ICT Resources in IB Physics

Electronic Edition

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ICT Resources in IB Physics, 2nd Ed.
by Inge H. A. Pettersen

Education is not about filling a bucket;
it's lightning a fire
William Butler Yeats

The whole art of teaching is only the art of awakening
the natural curiosity of young minds
for the purpose of satisfying it afterwards.
Anatole France, The Crime of Sylvestre Bonnard

... students should not only observe the execution of the experiments
with witch the truth, known until the present moment are demonstrated,
but also acquire the habit of making them with the sagacity and skill
required of the Explorers of Nature.
The 1772 statutes of the University of Coimbra (Portugal)[1]

Second Edition **August, 2004**

[1] Décio Ruivo Martins and Carlos Fiolhais, *A place of pilgrimage – the Coimbra Physics Museum*, Europhysics News, July/August 2003, pp. 154 – 156.

Contents

Acknowledgements

I have benefitted from many generous and resourceful students, teachers and company representatives in my search for useful ICT resources in IB Physics. In particular I want to thank the following persons:

- Fredrik Marøe, a computer wizard and a former IB Physics SL student at St. Olav vgs (Stavanger, Norway), has donated his Word template *IA_Template.rtf* to be used by future IB Physics students to get a nice IA cover,

- Kirsten Haaland, Michael Huy Le, and Michael Calder for supplying me with materials from their Extended Essays in order to make it possible to design examples of how ICT can be used in experimental work,

- Frank Skavland for supplying me with two units of VBA[2] code from his Extended Essay to show how one can transfer data from data analysis software (in this case the MPLI software) with properiterian file standards to Excel and how it is possible to design computational algorithms in Excel,

- Tobias Hobbesland, Ingunn C. Oddsen, and Yngve Svensen at St. Olav vgs (Stavanger, Norway) who have shared their expertice and their IB Physics ICT labs as documented in the booklet

  Tobias Hobbesland, Ingunn C. Oddsen, Inge H. A. Pettersen, and Yngve Svensen, *Active Teaching in Science* [Norwegian], St. Olav vgs, Stavanger (Norway) May 2002, ISBN 82-92374-00-0,

- Jeff McManus who has supplied the file *Exp vectors2001.rtf* corresponding to a generous offer in a message with subject line *Re: Force Tables* to the mailing list physhare Mon, 7 Oct 2002,

- Leo Takahashi who has supplied the file *Static and Kinetic Friction Experiment.rtf* corresponding to his article

  A Friction Experiment, The Physics Teacher, Vol. 40, Sep. 2002, pp. 374 – 375,

- Thomas Moses who sent the file *ConPendExp.rtf* corresponding to his article

  A New Twist for the Conical Pendulum, The Physics Teacher, Vol. 36, Sept.1998, p. 372,

- Salvador Gil who sent the file *Variable Mass Oscillator.pdf* based on his articles *Flow of sand and a variable mass Atwood machine* and *Variable mass oscillator* in

[2] Visual Basic for Application

American Journal of Physics July 2003 (for those who teach in Spanish, his web site http://www.fisicarecreativa.com about physics teaching is worth a visit),

- David E. Meltzer for sending me a CD of activities done at Iowa State University (by the way: you can also get the current version for free – see section *Ongoing Projects* on the webpage ISU PERG: Current Projects),

- Shannon Quigley at AIP who has given me permission to use graphics from the article

  Inge H. A. Pettersen, *Speed of Sound in Gases Using an Ultrasonic Motion Detector*, The Physics Teacher, Vol. 40, May 2002, pp. 284 – 286,

- Justine Brown and Steve Pon at Pasco Scientific and Christine Vernier at Vernier Software who answered my questions about equipment from their companies, and

- Pat Adams and David Jones at IB for helpful advice.

To all of those people I have forgotten to mention: thank you.

Preface

Motivation

The motivation for this collection of ICT resources is derived from two observations: The first observation is that many companies often design much too detailed labs for their ICT equipment. While such detailed can be initially useful for the teacher who starts using a particular kind of data logging equipment, these volumious labs lead to my second observation: A too detailed lab invariably encourages an authoriterian “cook book approach” to experimental physics. The end result is students who are consentrating to get all the details right by reading without having to think for themselves and without having to exchange viewpoints with their peers. This is in my opinion black magic and the opposite of what education really is about – training students to make informed decisions based on their own ideas and experiences. Personally I find a mixture of the modelling[3] methodology (David Hestenes, Arizona) and the Socratic Dialog Initiative[4] (Richard Hake, Indiana) to experimental physics a much better approach: Constructing understanding by interactions between student and student and between student and teacher is the main goal and the use of technology is only a mean to obtain this goal.

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Part I – labs

I have tried to be balanced and pragmatic in the sense that I have some moderately detailed labs even though most of the labs are of the slim variant. Since there are many different kinds of data logging equipment, I could not be too specific - again with some minor exceptions. Nevertheless, there has now been a period of standardization where most companies supply some archetypal sensors like motion sensor, smart pulley etc. The difference between the ICT tools is mainly the equipment set-up and the properiterian software for data analysis. A consequence of this “low noise” approach is that the teacher has to know by heart the set-up/calibration procedure for the various sensors. As the teacher in any case has to demonstrate the use of the various sensors for the class in any case, I consider the learning opportunities as a benefit :-).

Some labs consist of references to educational articles. Here the instructor will often find other ways of doing the lab. If a student considers a particular experiment very interesting and would like to work on an Extended Essay on the corresponding topic, both the article itself as well as the references therein might be useful as a starting point. Ideas from the case studies in part II could also be useful.

A word on ICT versus “ordinary labs”: I think it is important to do some manual labs with straightening graphs, learn to do a simple graphical analysis of linear graphs, to understand how to make a graph and in particular how to scale a graph.

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[3] URL http://modeling.la.asu.edu/ .
[4] URL http://www.physics.indiana.edu/~hake/ .

Part II – Extended Essays

In addition to general resources, I have given four case studies based on summaries of actual Extended Essays. They are by no means complete, but should give a very good idea of how ICT was used.

Equipment

I would also encourage you to buy a digital camera. The students may then effectively document their work in their lab reports. If your computers are connected in a network, you could upload the files on a particular network folder. A better way of distribution may be to let the students themselves transfer the pictures to a movable storage medium. This camera will also be useful for Extended Essays and for Group 4 project work.

Professional data-acquisition (DAQ) hardware and software like the Educational Laboratory Virtual Instrumentation Suite[5] (ELVIS) from National Instruments are approaching the cost level of the traditional educational data logging systems. Consider the possibility of having one computer with this level of sophistication dedicated to work on Extended Essays.

Future

Since I have still a lot of raw materials and ideas which I have not got time to make presentable, I plan to upload a version 2 of this document in July 2004 to the home page http://home.no.net/ingehap/ . If you have a lab you think will be useful for other IB teachers and you are willing to share them in this second version, you may send them to ingehap@start.no . I will then give full credit in an acknowledgement section at the end of the lab (see for instance the lab "Conical Pendulum Experiment" in this document).

[5] Doug Tougaw, *National Instruments Records a Hit with ELVIS*, Computing in Science & Engineering, Nov./Dec. 2003, pp. 10 – 12.

In the matter of physics,
the first lessons should contain nothing but
what is experimental and interesting to see.
A pretty experiment is in itself often more valuable than
twenty formulae extracted from our minds.
Albert Einstein

Part I - ICT Labs

Absolute Temperature

Syllabus reference	3.3.1
Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	One week after delivered out
Aim	Make an estimate of the absolute temperature

Equipment

CBL2
Biology Gas Pressure Sensor
Rubber stopper apparatus
Temperature Probe

Measurement procedure

1. Set up the CBL2 to use the Biology Gas Pressure on channel 1 (unit: kPa), the Temperature Probe (unit: ºC) on channel 2 and to collect data in the Log Data mode.

2. Connect the Biology Gas Pressure Sensor to the rubber stopper apparatus with a gentle half turn.

3. The other end of the rubber stopper apparatus is then inserted into an Erlenmeyer flask. Make sure that the second valve is closed, so that we have a constant volume gas sample.

4. Place the flask in water baths of different temperatures (see picture) and write up corresponding temperature/pressure values.

   Make sure that the temperature probe has come to equilibrium with the water baths.

Data Analysis

1. Present pressure vs temperature in Excel with estimated uncertainty bars for pressure (200Pa) and temperature (0.2ºC). This graph should be part of your delivery.

   On the graph in Excel make the scales and upper and lower bounds such that it is possible to read off the crossing of the best fit line with the temperature axis.

2. Estimate the absolute temperature with uncertainty using your data.

3. Make a linear best fit in Graphical Analysis of pressure (Pa) vs temperature (K) where the standard value for the absolute temperature is assumed.

   Where should the line cross the pressure axis and why?
   What does the gradient of the line represent?

Acceleration of a Lift

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Aim

Determine the acceleration of a lift by measuring the force acting on an object inside the moving lift.

Equipment

CBL-system with TI-83 calculator, force probe, 3×100 g masses and stand.

Four measurements

I One measurement when the lift is at rest.
II One measurement when the lift is moving from floor 2 to floor U .
III+IV Two measurements when the lift is moving from floor U to floor 2 .
NB ! Each measurements should be saved as PIC variable (PIC1, PIC2, PIC3 and PIC4).

Experimental procedure

The result of the experiments are pictures showing the force along the y-axis as a function of time along the x-axis:
1. Turn on the CBL and the calculator. Make sure they are firmly connected.
2. Start the program FRICTION.

3. From SCALE OPTIONS choose MANUAL SCALE.
4. Choose the boundary values and steps for the force along the y-axis:
    Ymin=2.5
    Ymax=3.5
    Yscale=0.1
5. Remove any weight hanging from the probe to zero the probe.
6. Hang 300 g mass from force probe.
7. Now you are ready to start the measurement:
I Be sure the masses are at rest before you start the measurement. Save as PIC1.
II, III, IV Repeat steps 2-6. Start the data collection and half a second later start the lift. Save PIC2, PIC3 and PIC4.

Data analysis

1. Give explanations to each of the graphs in II and III. Comment also the difference between the graphs of the force functions.

2. Determine the maximum acceleration of the lift from floor U to floor 2. Use the average value from measurements III and IV.

3. Are two measurements enough for obtaining a good value for the acceleration ? Give reasons for your answer.

Acceleration of Gravity

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the acceleration of gravity by various methods.

The teacher should, depending on the time constraints and on the amount of equipment in the lab, make a decision on which of the following independent units the students should do. The remaining units can be used for extension.

Equipment

Force sensor, motion detector, photogate, light intensity sensor, smart pulley, accelerometer
Mass scale
Ball, weights of different masses, picket fence
thread (unstrechable)

Unit 1 – Acceleration of gravity by force measurements

For each weights measure the mass by a mass scale and weight by a force sensor. Determine the gradient of a plot of weight versus mass.

Unit 2 – Acceleration of gravity by distance measurements

Determine the acceleration of a ball falling towards a motion detector placed on the floor. Use a data analysis program to fit the distance data vs time to a quadratic function. Compare the result with the slope of velocity (numerical differentiation in the program) vs time.

NB! Stop the ball from hitting the detector!

Unit 3 – Acceleration of gravity by dropping a picket fence I

Determine the acceleration of a picket fence falling through an infrared photogate. Use a data analysis program to fit the distance data vs time to a quadratic function. Compare the result with the slope of velocity (numerical differentiation in the program) vs time.

Unit 4 – Acceleration of gravity by dropping a picket fence II

Redo part 3 with the photogate replaced by a light intensity sensor.

Unit 5 – Acceleration of gravity by a smart pulley ("Atwood's Machine")

Put the string around the pulley and bind two masses m and M (M > m) on each end of the string. Show that the acceleration is $a = (M - m)g/(M + m)$ and use this equation to determine the acceleration of gravity.

Unit 6 – Acceleration of gravity by an accelerometer

Let an accelerometer be in free fall and measure the acceleration.

NB! Let it hit a smooth surface (cloths).

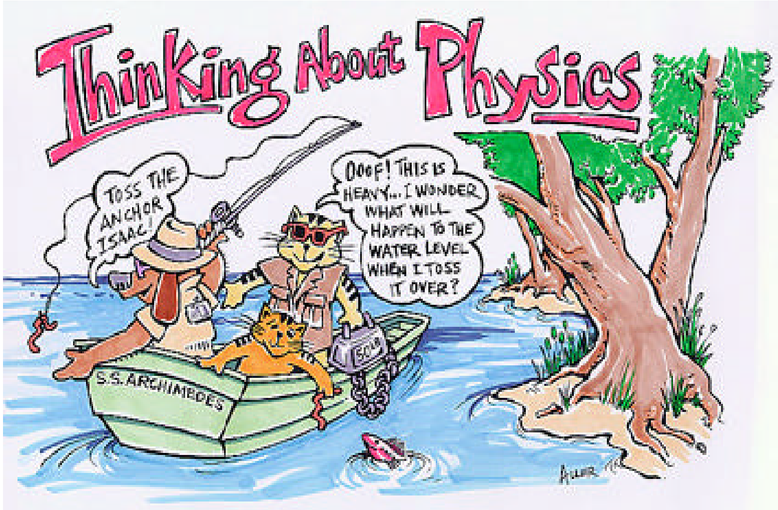
Reference

W. J. Leonard, *Dangers of Automated Data Analysis*, The Physics Teacher, Vol. 35, Apr. 1997, pp. 220 - 222.

Archimedes' Law

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the acceleration of gravity by various methods.

Based on the following disussion make your own hypothesis of the correct answer:

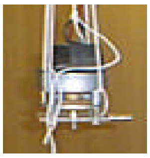


After making a hypothesis, plan an experiment that can decide which point of view is correct. Do the experiment and evaluate! All IA criteria should be covered.

Beats in an Oscillator Near Resonance

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment



Mechanical speaker with an oscillating axial piece of metal (adjustable freqency)

Spring

Mass

Motion detector sensor

Procedure

Determine first the natural frequency of the spring/mass system.

Hang the mass from the spring whose other end is connected to the axial oscillating metal piece of a mechanical speaker where the speaker is hung from the ceiling. Put the motion detector below the mass. If the mass has a small reflecting surface, glue a card of stiff paper to the mass.

Measure now the distance versus time when the frequency of the speaker is increased from zero towards the natural frequency of the spring/mass system. Do a similar measurement when the frequency starts much higher than the natural frequency and is lowered towards the natural frequency.

Question

Explain what happens when the external frequency is close to the natural frequency.

Reference

Chris A. Gaffney and David Kagan, *Beats in an Oscillator Near Resonance*, The Physics Teacher, Vol. 40, Oct. 2002, pp. 405 – 407.

Biomedical Physics
A Visit to a College/University

Syllabus reference	Biophysics
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	
Aim	Make six medical investigations

During the visit you are supposed to complete 6 investigations, 30 minutes each.
The investigations are:

Investigation 1 :	X-rays - demonstration of principles
Investigation 2 :	Measurement of arterial pressure - indirect method
Investigation 3 :	Audiometry - measurement of air conduction
Investigation 4 :	Ultrasound imaging
Investigation 5 :	ECG – Electrocardiography
Investigation 6 :	Measurement of blood flow and arterial pressure by use of ultrasound (Doppler effect).

You will be grouped in size of three. Group 1 starts with Investigation 1 and goes on to Investigation 2, group 6 starts with Investigation 6 and goes on to Investigation 1 etc.

X-Rays – Demonstration of principles

1. Make a sketch of the apparatus

2. What range of acceleration voltages can be chosen?
   Compute cut-off wavelengths from these data (at home)

3. Explain the use of photographic film for X-ray imaging.

4. Describe and explain standard X-ray imaging techniques.
   - Fluoroscopic image intensification for soft tissue => Barium meal
   - Moving source/film tecnique

Measurement of Arterial Blood Pressure

You are here going to study an indirect technique using inflatable arm cuff, stethoscope and mercury manometer:

1. Explain why arterial pressure may be measured in the brachial artery of the arm at heart level? (i.e. why this is a good approximation to the pressure in aorta.)

2. Place the arm cuff at heart level and inflate it to manometer shows 200mmHg. While listening for Korotkoff sounds below arm cuff, lower cuff pressure slowly (1mmHg/second). The pressure at which the Korotkoff sound first appears is taken as the systolic pressure. As cuff pressure is lowered a point is reached when a sudden diminuition in the Korotkoff sound is heard. The corresponding pressure is taken as the
diastolic pressure. Repeat 3 times (change arm) for patient at rest and 1 time for patient immediately after heavy exercise.

	Systolic pressure	**Diastolic pressure**
At rest, attempt 1		
At rest, attempt 2		
At rest, attempt 3		
After exercise		

Audiometry – Audiogram for Air Conduction

In this investigation you will determine the ear's threshold of hearing as a function of frequency. Follow the instructions handed out at the site. Paste the audiogram(s) onto this page.

Ultrasound Imaging

1. Make a sketch of the arrangement of the apparatus and the patient.

2. Explain how an image can be obtained by a pulsed array technique.

ECG - Electrocardiography

1. Make a sketch of the apparatus with electrodes connected to patient.

2. Paste your own electrocardiogram onto this sheat.

3. Identify the P wave, QRS complex and T wave on your ECG, and connect them to the cardiac cyc le.

Measurement of Blood Flow and Arterial Pressure – Doppler Effect of Ultrasound

1. Repeat investigation 2, but use an ultrasound flow transducer instead of stethoscope to determine the systolic and diastolic pressure:

	Systolic pressure	Diastolic pressure
At rest, attempt 1		
At rest, attempt 2		
At rest, attempt 3		
After exercise		

2. Use the ultrasound flow transducer to determine (qualitatively or quantitatively) the flow velocity in different parts of the arm. Explain your method.

3. Explain the nature of the sound measured by the transducer and explain it's origin.

Blackbody Radiation

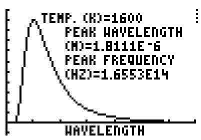
Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Simulate blackbody radiation

Equipment

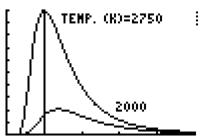
TI82/83 Calculator
The file **blackbod.zip** (downloadable from the archive http://www.ticalc.org/search/)

Procedure

Run the "BLACKBOD" program on a TI-82 or a TI-83 calculator. Two types of graphs can be produced with the simulation. One type is produced when a single temperature is supplied:



The other type is produced when two temperatures are supplied:



Note that the temperature(s) is/are in kelvin (K).

Blackbody Radiation Questions

1. As the temperature of an object decreases what happens to the peak wavelength? As the temperature of an object decreases what happens to the peak frequency?

2. In a thermonuclear blast, the temperatures at the blast site("ground zero") reach 1 x 109 K! What is the peak wavelength and peak frequency during the explosion? In what region of the electromagnetic spectrum does this peak fall in?

3. In 1965 two Bell Telephone physicists, R.A. Penzias and R.W. Wilson, were using a horn-shaped antenna designed to pick up signals from Earth orbiting communication satellites. In the signals that they received they kept on detecting a radiation that seemed to come from all directions. Later that year R.H. Dicke and his Princeton coworkers showed that this background radiation (at 2.73 K) was a remnant of the creation of the universe ("big bang"). What is the peak wavelength and frequency of this cosmic background radiation? In what region of the electromagnetic spectrum does the cosmic background radiation exist?

4. The sun can be considered to be a blackbody radiator. The peak wavelength emitted by the sun is 460 nm. What is the surface temperature of the sun?

5. The temperature of a light bulb depends on the resistance of the resistor inside the bulb. As the current passes through the bulb, the resistor in the bulb heats up and thus radiates electromagnetic radiation. The temperature (T) of a resistor (in kelvin) inside a particular bulb depends on the equation $T = (113\ R)^{0.830}$ where R is the resistance of the resistor. If a potential difference of 9.00 V is applied to this bulb, the current passing through it is 0.156 A. Determine the temperature of the filament inside the bulb. What is the peak wavelength of the radiation emitted by the bulb in nanometers? In what region of the electromagnetic spectrum is this peak in? Explain how the bulb is able to emit visible radiation even though the peak is not in the visible region.

Acknowledgement

This simulation is a formatted version on the Word document (by an anonymous writer) that is included in the zipped file **blackbod.zip**.

Bouncing Ball

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Prelab work (home)

A ball is dropped from a certain height and starts bouncing on the floor. Make a sketch of the following graphs showing the movement from the time the ball is dropped to the time of the fourth bounce:

1. a position vs time graph
2. a velocity vs time graph
3. a speed vs time graph
4. an acceleration vs time graph
5. a kinetic energy vs time graph
6. a potential energy vs time graph
7. a total mechanical energy vs time graph

Design a procedure involving the motion detector to experimentally check your results. When you enter the classroom, please deliver the graphs to your teacher.

Group work (start of lab)

Within 15 min discuss the predictions in the homework and agree on a procedure for checking the results.

Data Collection

Execute your plan. Write down your initial height!

Data analysis

For the following problems I want a printout of the seven graphs for each member as evidence for the work you have done.

Choose a part, i. e. a time window, of the graphs between two successive bounces. Make a best fit to a constant graph, a linear graph, or a quadratic graph for each of the seven graphs for the same time window according to what you think is the best model.

Questions

How do the experimental results compare with your prediction?

Can you explain why you get a constant graph, a linear graph, or a quadratic graph in the seven experimental graphs?

Bouncing Ball Revisited

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Challenge

The aim of this lab is to answer the following problem: How long does it take a bouncing ball to stop its motion?

An approximate answer can be found in terms of the initial heigh H, the acceleration of gravity g, and the coefficient of restitution w (the presumed constant ratio of the speed immediately after any bounce to the speed immediately before this bounce):

$$T = \frac{(1+w)}{(1-w)} \cdot \sqrt{\frac{2H}{g}}\ .$$

Use the data from the assessment "Bouncing Ball" and the formula above to make a prediction of the total time T. Do you consider the answer reasonable?

Plan an experiment where you are using the microphone to test the validity of this result.

Data Collection

Discuss the various plans in your group before you start data collection.

Acknowledgements

S. K. Foong, D. Kiang, P. Lee, R. H. March and B. E. Paton, *How long does it take a bouncing ball to bounce an infinite number of times?*, Jan. 2004, Physics Education, pp. 40 – 43.

Bridge N J 1998, *The way balls bounce*, Physics Education, Vol. **33**, pp.174–181.

Bernstein AD 1977, *Listening to the coefficient of restitution*, Am. J. Phys. Vol. **45**, pp. 41 – 44.

Smith PA, Spencer C D and Jones D E 1981, *Microcomputer listens to the coefficient of restitution*, American Journal of Physics, Vol. **49**, pp. 136–40.

Stensgaard I and Laegsgaard E 2001, *Listening to the coefficient of restitution – revisited*, American Journal of Physics, Vol. **69**, pp. 301 – 305.

Aguiar C E and Laudares F 2003, *Listening to the coefficient of restitution and the gravitational acceleration of a bouncing ball*, American Journal of Physics, **71**, pp. 499–501.

Bows and Arrows – Potential Energy

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

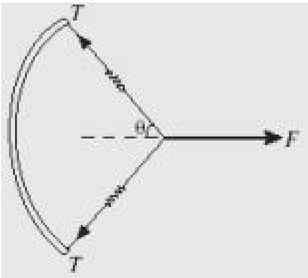


Fig. 1

Part 1 – Potential energy of a bow

Clamp the bow horizontally and tie a piece of string to the middle of the bowstring and let it pass over a pulley.

1. To the free end of the string add various masses and measure the corresponding extension.

2. Make a force-extension graph of your data in Graphical Analysis.

3. Use the area below the graph to make a new graph of potential energy vs. displacement.

Part 2 – Predicting maximal height of an arrow

1. Use the result under part 1 to estimate the displacement needed to shoot an arrow 1m and 1.5m vertically upwards.

2. Test your calculations in part 1 in the schoolyard.

Questions

1. Discuss the results in part 1: How could you experimentally obtain a more accurately potential energy vs. displacement graph?

2. Discuss the results in part 2: What are the reasons for the differences between theory and experiment in part 2?

References

Robert Hardy, *Longbow: A Social and Military History,* Patrick Stephens 1992.

Boyle's Law

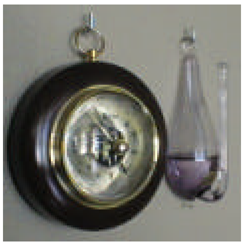
Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

ChemBio program
Biology Gas Pressure Probe

Procedure

1. Measure the external air pressure by reading the barometer:



2. When the valve is open (see figure below) let the volume in the syringe be 10cc:

3. Close the valve by turning it 180^{o} .

4. Make measurements of the pressure for values of the volume in the range 5 cc to 14cc. These measurements should be done at least two times.

Data analysis

1. Use Excel to make two scatter graphs: One graph for pressure vs volume and one for pressure vs inverse volume. The graphs should contain the pressure in the unit kPa.

2. Do the graphs fullfill the Boyle law?

Find the uncertainty from one of the graphs the air volume that is inside the sensor and the pipe.

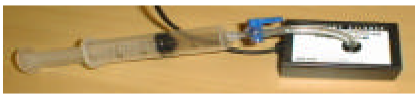
Boyle's Law and the Gas Constant

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Gas Pressure Sensor
Thermometer

Procedure


Picture 1


Picture 2

1. Set up the CBL2 to use the pressure probe on channel 1 (unit kPa) and put it in Log Data modulus.

2. Connect the syringe to one of the valves with a half twist.

3. Close the valve leading to the pressure sensor with the blue control (see picture 1) and set the syringe to have volume 10ml.

4. Close the valve such that the syringe is connected to the pressure sensor (picture 2).

5. Measure the pressure from 10ml in steps of 1ml down to 6ml. Measure then from 6ml to 13ml in steps of 1ml and finally from13ml to 10ml. Write down the pressure values.

You have now three values for 10ml, one value for 6ml and 13ml as well as two values for the other values.

Data analysis

1. For those volume values with more than one pressure, calculate the arithmetic average. Estimate also the uncertainty by calculating half the variation.

2. In this experiment there is a serious systematic error: We have neglected the fact that the pressure probe itself as well as the pipe between the syringe and the probe contains a colume of air B. In oerder to determine this extra volume we make a curve fit in Graphical Analysis on the form $y = \frac{A}{x+B}$ where y is the pressure in Pa and x is the volume in m^3. What values do you get for A and B?

3. According to the ideal gas law the constant in the previous section is A=nRT. If you then know the room temperature and the number of mols, the gas constant R can be calculated. Read of the room temperature and use the volume (10+B)ml, the density 1,26kg/ m^3 and molar mass 29g/mol, to calculate R. What is the percentage deviation from the accepted value?

Extension

Present pressure vs volume in Excel with uncertainties for the pressure.

Centripetal Force

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Force sensor
Photogate
String
Meter stick

Pre-lab exercise for unit I

For a simple pendulum derive by Newtons second law an expression that expresses the centripetal force on the bob at the lowest point in terms of the weight of the bob and the tension force acting on the bob.

Pre-lab exercise for unit II

Use conservation of energy and the expression in the previous exercise to show that the tension force at the lowest point is a linear function of the height of the bob above the lowest point when it is released.

Unit I

Use the force sensor to measure the tension at the lowest point (maximum tension) and the photogate at this point to determine the speed. Measure tension and speed for various initial heights of the bob.

Make a best fit of the tension force at the lowest point as a function of the speed squared at the same point. Make an interpretation of the gradient and the intercept with the second axis.

Unit II

Remove the photogate and measure the maximum tension as a function of the released height. Use the pre-lab exercise for unit II to check the linear relation.

Conical Pendulum Experiment

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Introduction

We will use a conical pendulum to measure the acceleration g due to gravity. The conical pendulum consists of a ball at the end of a string; the upper end of the string is fixed and the ball orbits in uniform circular motion as shown in Figure 3, so that the string sweeps out the surface of a cone. By tying the upper end of the string to the force sensor, we can use the force sensor to measure both the horizontal force required to keep the ball moving in a circle and the orbital period.

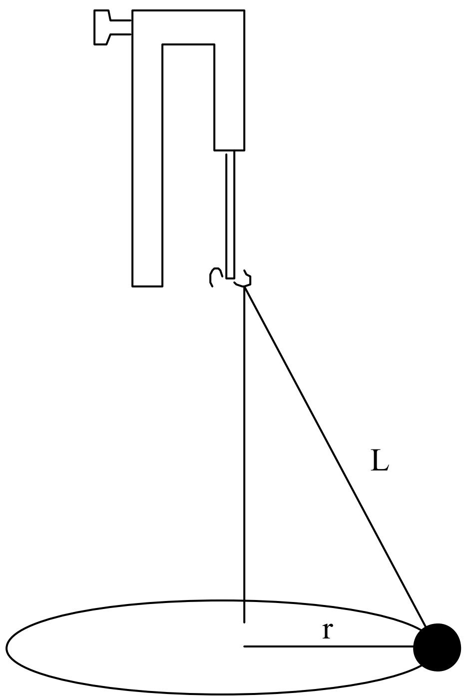


Fig. 3. Schematic of the conical pendulum.

Procedure

1. Calibration of the force sensor:

a. From the Main Menu of the application *Motion Plotter*, select "Other Options."
b. Check that the settings are:

Motion Detector:	Channel A
Force Transducer:	Channel B
Motion Detector Type:	Analog
Sampling Rate:	30 per second
Motion Detector Delay:	25 counts
Averaging:	1 reading

c. Go to "Calibrate Force Transducer."
d. Select "Yes."
e. The units of force should be Newtons (N).
f. At this point, the program asks you to remove all weight from the force sensor. To do this simply hold the force sensor so that its flexible strip is horizontal and place the ball on the table so its weight is off the flexible strip (see Figure 4).
g. Now hang 500 g from the S-hook, taking care to keep the flexible strip horizontal. When the count stabilizes, type return.
h. Enter the force in Newtons ($0.500\ kg \times 9.80\ m/s^2 = 4.90\ N$). Type return and return to the Main Menu.

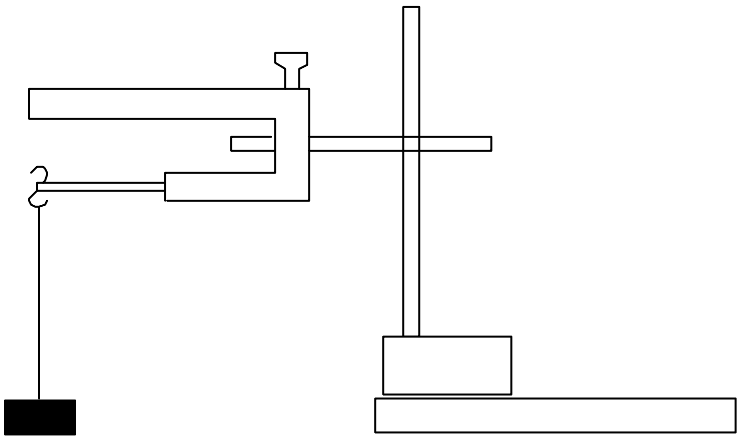


Figure 4. Set-up for calibrating the force sensor.

2. Measure the length of your pendulum (from the center of the ball to the point where it is attached to the force sensor, with the string moderately taut). Measure the radius of the reference circle.

3. Hold the force sensor so the flexible strip is vertical as shown in Figure 3. Practice making the ball orbit in uniform circular motion above the reference circle.

4. When you are reasonably good at this, you are ready to acquire the data from the force sensor.
a. From the Main Menu, select "Monitor/Graph in Real Time."
b. Bypass the "Graph Style Options" menu by typing return.
c. In the "Real Time Graphing" menu, check that distance, velocity, and acceleration are OFF, and force is ON. A good range for the force values is -2 N to 2 N. Set the Time-of-Run to 25 seconds. Select G to proceed to the graphing display.
d. Start making the ball orbit over the circle and have another person type return to activate the data acquisition. The plot should look like a sine wave. Before proceeding,

discuss the following questions with your lab partner(s) (you need not write out answers in your lab report):

Why is the plot sinusoidal? How can the force vs. time plot be used to find the horizontal component of the tension in the string? How can the orbital period be deduced from the force vs. time plot?

e. From the "Graph Follow-Up Options" menu, select "Examine Data." You can use the arrow keys to position the cursor through your data and view the time and force coordinates. Record the time and force coordinates of the first five crests and troughs. You can use this data to calculate the horizontal force and the period. The horizontal force is the half the amplitude from the top of a crest to the bottom of a valley. The period is the time between two crests (or between two troughs). An accurate way to measure the period is to measure the time for N periods and then divide by N.

f. Each lab partner should perform the experiment. Record the period and horizontal force amplitude obtained by each lab partner; then average the results to obtain your group's best measurement of the period and horizontal force.

5. Try to predict the following: If you make the ball orbit in a larger circle that the reference circle, what will happen to the magnitude of the horizontal force? What will happen to the period? After making your predictions, try the experiment.

6. Weigh your ball using the force sensor. The force sensor's flexible strip should be horizontal and the ball hanging motionless for a reliable measurement.

Questions

1. Derive an algebraic expression for the period τ of the uniform circular motion in terms of the quantities g, r, and L, where g is the acceleration due to gravity, r is the radius of the circular orbit, and L is the length of the pendulum.

2. Using the expression you derived in Question (1) and your experimental data, calculate the acceleration g due to gravity. Find the percent difference between your experimental value for g and the accepted value $g = 9.80\ m/s^2$.

3. Derive an algebraic expression giving the mass m of the ball in terms of the horizontal component of the tension force F_h in the string, the orbital period τ, and the radius r of the orbit.

4. Using the expression you derived in Question (3) and your experimental measurements of F_h, τ, and r, calculate the mass of the ball. Find the percent difference between your experimental value for m and the value you measured directly in Procedure 6.

5. Is it physically possible to whirl a pendulum around in a horizontal plane with the string perfectly horizontal? Explain.

Acknowledgements

Thanks to Thomas Moses who sent me the file ConPendExp.rtf corresponding to his article *A New Twist for the Conical Pendulum* in The Physics Teacher, Vol. 36, Sept. 1998, p. 372. This lab is with minor changes his worksheet.

Two other possible approaches to circular motion with the force sensor is given in Bill Jameson, *Additions to a Circular-Motion Lab*, The Physics Teacher, Vol. 37, Dec. 1999, pp. 545 – 546 and in J. L. Makous, *Variations of a Circular-Motion Lab*, The Physics Teacher, Vol. 38, Sep. 2000, pp. 354 - 355.

Data Processing and Presentation Using ICT

Syllabus reference	1.3 Mathematical and Graphical Techniques
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	
Aim	Show how ICT can be used to make processing and presentation of data more efficient

Table of Contents

Part 1 – An example on how to process and present data

1.1 Data presentation with Excel[1]

The speed vs. time data for a freely falling golf ball is shown in figure 1 below:

Time t/s	Velocity v/m/s
0,067	1,20
0,1	1,60
0,13	2,00
0,16	2,10
0,2	2,60
0,23	3,00
0,26	3,20
0,3	3,30
0,33	3,80

Fig. 1 Raw data of experiment

Your task is to present these data with uncertainty bars, given that absolute uncertainty in time is 0.03s and absolute uncertainty in velocity is 0.1m/s.

Write first the data into a Excel so that the result is similar to figure 2:

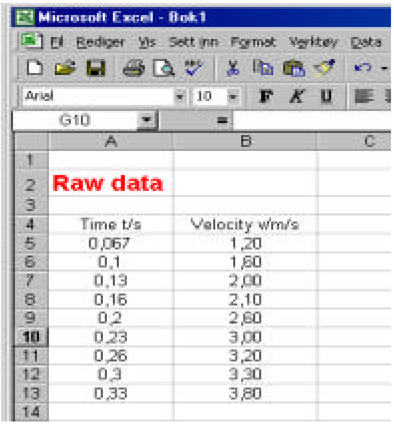


Fig. 2 Raw data in Excel

Select now the region A4:B13 and click the icon for the diagram wizard. In the resulting screen you should choose scattering diagram and select the first subtype:

[1] Microsoft Excel ®

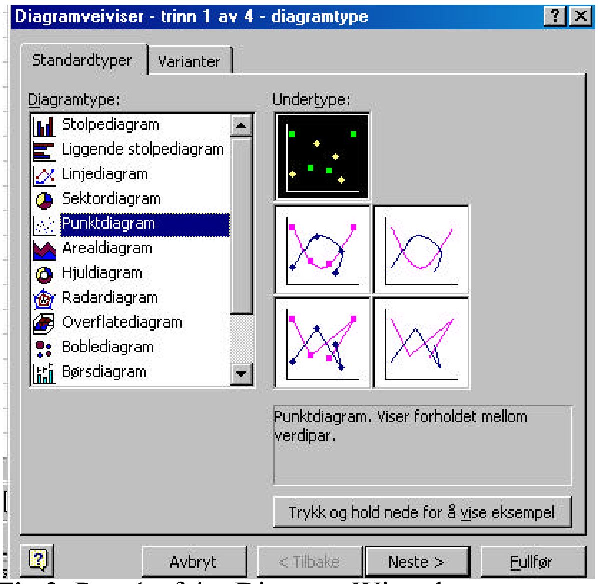


Fig 3. Part 1 of 4 – Diagram Wizard

Selecting "Next" two times, the following picture appears:

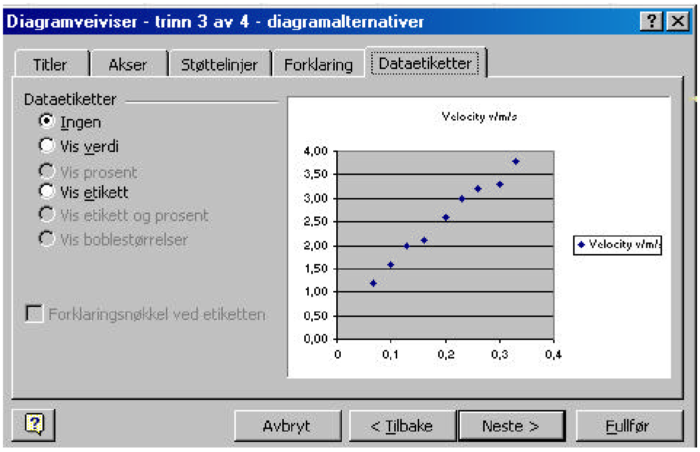


Fig 4. Part 3 of 4 – Diagram Wizard with default tab

Choose the title tab and write in title and text along the coordinate axes:

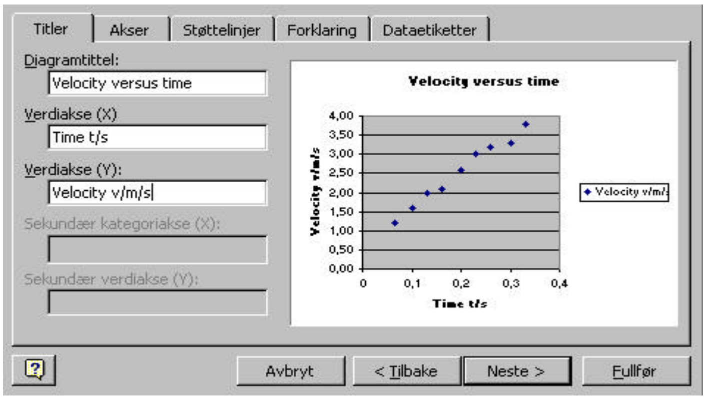


Fig 5. Part 3 of 4 – Diagram Wizard with title tab

Note the following important points:

- The title is short and precise, telling what the drawing is all about.
- Along both the x-axis and y-axis name, symbol, and unit are all given for each physical quantity.

On the tab for auxiliary lines, cross away the default selection. Thus no lines appears:

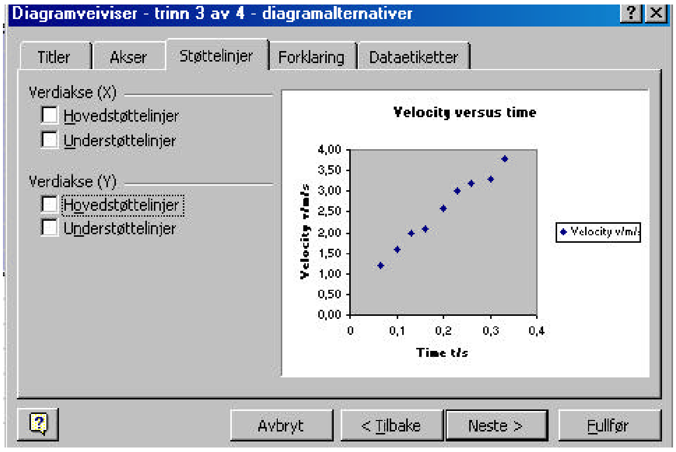


Fig 6. Part 3 of 4 – Diagram Wizard with title tab

On the explanation tab cross away the default for explanation. Since you have only one curve in the diagram the title should be good enough to explain what the data are all about. Choose then "Next" and select "New sheet" before you push the "Finish" buttom:

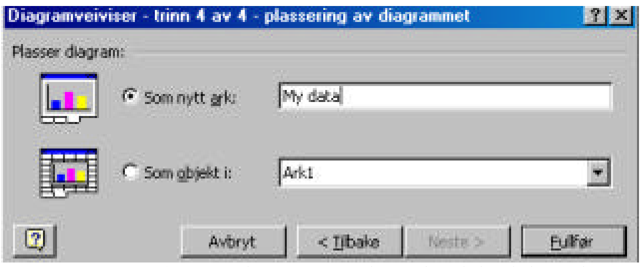


Fig 7. Part 4 of 4 – Diagram Wizard with title tab

The result should then be similar to the following picture:

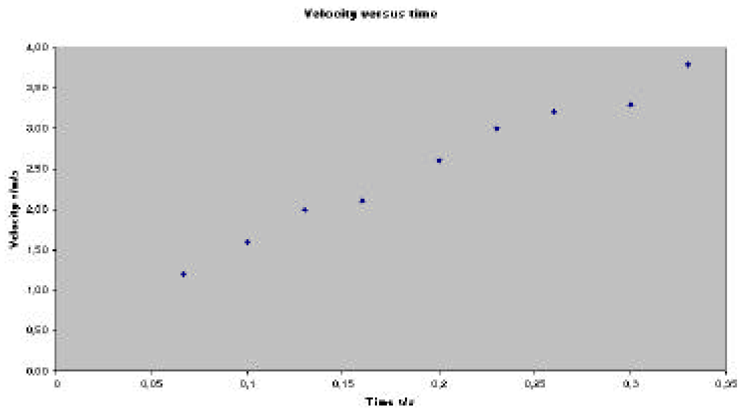


Fig 8. Resulting diagram after use of the wizard.

It is rather unusual to use a shaded background for presentation of data. Double-click therefore the shaded background so that the following picture appears:

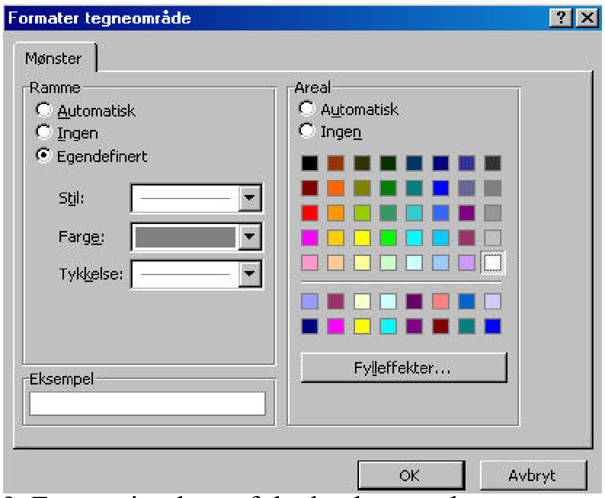


Fig 9. Formatting box of the background.

In the region “Area” click the white choice and then the “OK” buttom. The background is now white.

Point now on one of the data points and double-click. The result is a collection of tabs where you choose the “x error field” tab:

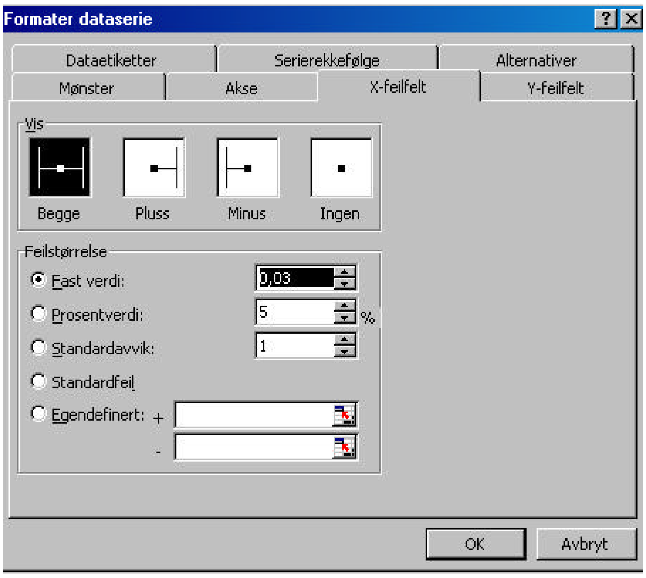


Fig 9. Formatting series of data.

Choose double uncertainty bar and fixed value 0.03. Quite similar for the "y-error field" tab, a double uncertainty bar of fixed value 0.1 is chosen.

By choosing "OK" the final graph emerges:

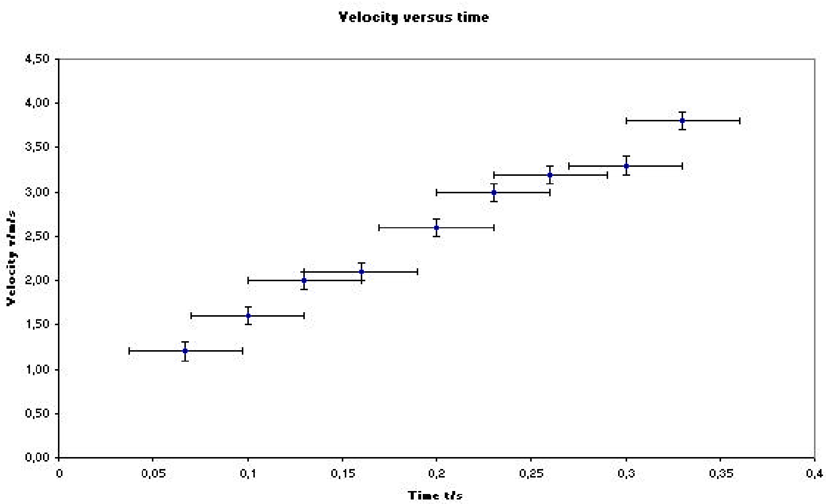


Fig 10. Final graph!

The lower and upper values on the coordinate axes, units etc. may be changed by double-clicking these axes and selecting the "Scale" tab. Change the coordinate axes above so that

- The least and the largest value on the x-axis are respectively 0.01 and 0.38.
- The least and the largest value on the y-axis are respectively 0.50 and 4.30.

1.2 How to transfer a graph on your screen to a Word document

After all this hard work you want to transfer this beautiful art to your lab report in Word.

The idea behind this is very simple: With the graph centered on your screen, push the PrntScrn bottom on your keyboard to make a picture of the screen. Start up Word and push the paste icon. The result is a picture of your screen.

In order to cut away the the part of the picture that does not belong to the graph, choose Show/Work Tools/Picture to get the picture tool bar. Left-click first the picture and then choose the cut icon .

Point now with the cursor on the middle black square on a boundary of the picture, left-click and hold the mouse and push the mouse towards the center of the picture. This operation may also be done in reverse if you cut too much. Do the same operation for the three other boundaries.

When you are finished, close Word and start up Graphical Analysis in order to do the next section.

1.3 Data analysis with Graphical Analysis

In Graphical Analysis open the file freefall.dat by clicking the open icon. The resulting screen image should be similar to the following:

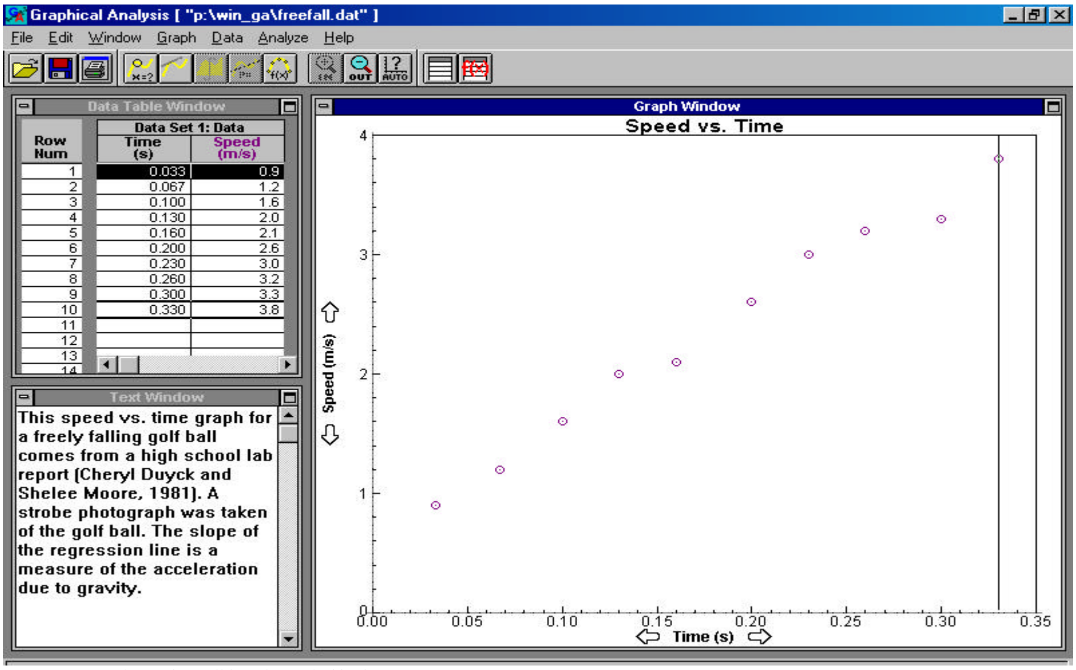


Fig 11. Data for the file freefall.dat.

In accordance with the theory for free fall without friction the velocity/time data seem to be along a linear graph. Let us try to find a best fit line:

In the Graph Window select now all the points with the mouse. Choose then Analyze/Analytic Curve Fit on the menue. On the resulting dialog box select the linear function and push the OK bottom:

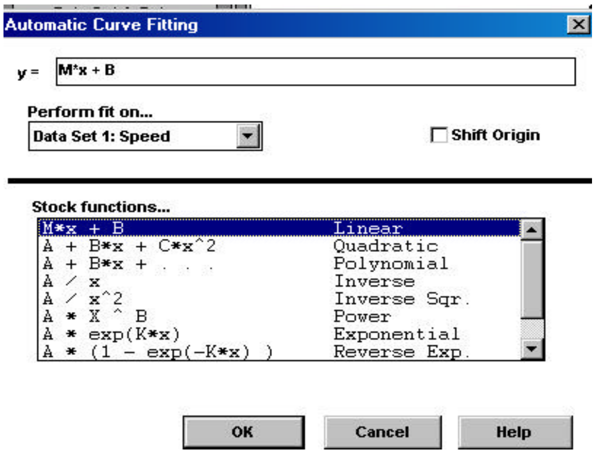


Fig. 12. Automatic Curve Fitting Dialog Box

On the next screen push the "OK- Keep Fit" bottom. The resulting picture should be

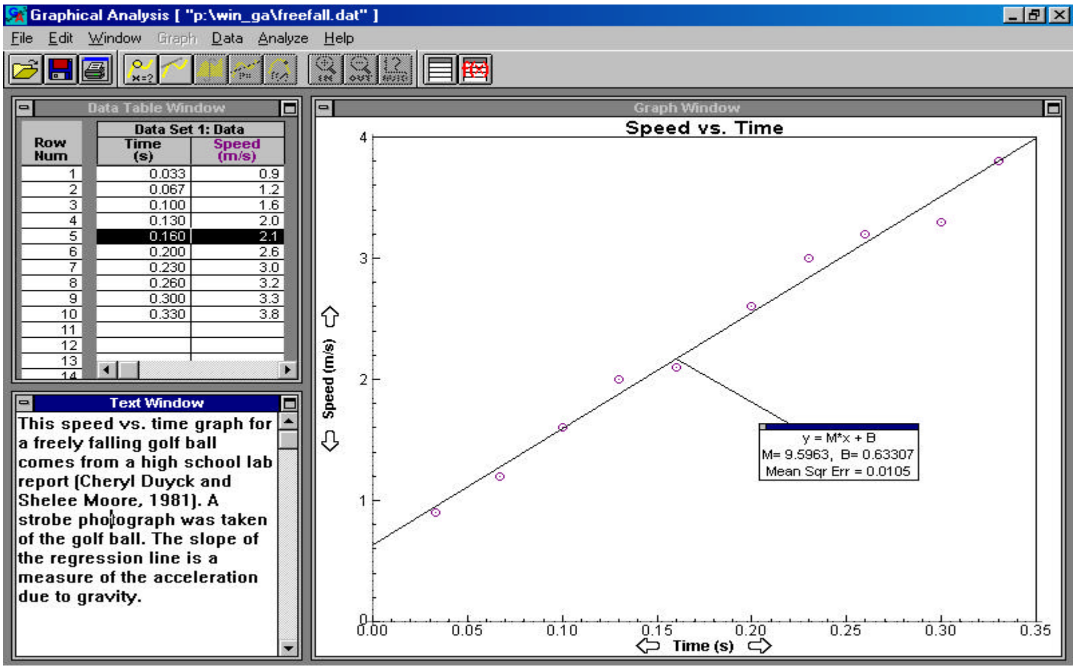


Fig. 13. Best fit line for the freefall data.

What is the acceleration of gravity according to this analysis? What about initial ve locity?

Part 2 – Two assessed exercises

2.1 Distance traveled for a ball rolling from rest down an inclined plane

The data below represent the distance traveled for a ball rolling from rest down an inclined plane. The timing was done using a waterclock in an attempt to duplicate the work of Galileo.

Time (ml H2O)	Distance (m)
90	4.570
84	3.960
72	3.050
62	2.130
52	1.520
40	0.914
24	0.305

The uncertainties in time and in distance are respectively 4ml and 0,05m.

a) Make a presentation in Excel of distance versus time.

b) Make a presentation in Excel of distance vs. time square (Hint: Make a new coloumn and use a spreadsheat formula).

c) Use a print-out of the result in b) and a steepest and a least steep line within the uncertainty bars to determine the acceleration with uncertainty.

Remember that the best value is the average of the two extreme values and the absolute uncertainty is half the difference between these two values.

d) Assume that the distance is proportional to a power of time. Make a best fit in Graphical Analysis to determine the exponent and the proportionality factor.

e) Explain why the exponent in d) should be 2.

e) What is the acceleration from the results in d)?

f) Compare the values of the acceleration in c) and e).

2.3 Historical data gathe red by Boyle

The following historical data[2] were gathered by Boyle in his study ofthe relationship between the volume and pressure of a gas at a constant temperature:

Volume V/cm^3	Pressure p/mm Hg
27,94	811
25,4	897
22,86	999
20,32	1122
17,78	1278
15,24	1494

[2] Morris H. Shamos, "Great Experiments in Physics", Dover 1959.

13,97	1627
12,7	1795
11,43	1978
10,16	2232
8,89	2551
7,62	2986

Assume that the absolute uncertainty in volume is $0,2cm^3$ and that the absolute uncertainty in pressure is $10mm\ Hg$.

a) Present the values of pressure vs. volume (with uncertainties) graphically.

b) Assume the pressure is inverse proportional to volume for a fixed temperature. Determine the constant for this inverse proportionality. (Hint: Use a best fit formula).

Part 3 – Optional Exercise

By dropping a ball from rest towards a Motion Detector (but not hitting!), obtain data of distance versus time for this ball. The Motion Detector has an absolute uncertainty of $1mm$ and the time values may be considered to be without any uncertainty.

a) Make a plot of distance versus time with uncertainties.

b) Determine the acceleration of gravity with uncertainty.

Possible extensions

1. Use table function in Word to make a Caption to all graphs.
2. Make new voloumns in Graphical Analysis.
3. More examples.

Physics Activity

Page
Ver.

Last updated

Decay of Diceonium

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

100 dices for each group
A tray for each group
A spreadsheet

Part 1 - Procedure

Chose one of six faces of a dice as a decayed state, say the six dots state. Put all the dices into the tray and shake it. Count all dices with a decayed state, write down the number, and remove these dices. Repeat this procedure several times until you have less than five dices left.

Make a plot in a spreadsheet of the dices remaining as a function of the number of shakings.

Make an exponential best fit to the datea in Graphical Analysis.

Questions

- What is the half-life of "diceonium" as seen from the graphs in part 1?
- What will happen to the half-life if the probability of getting a decayed state is increased?

Part 2 – Testing your predictions

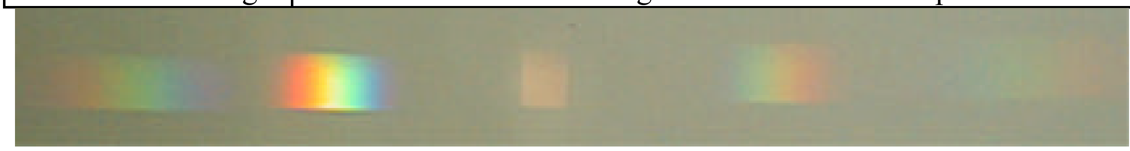
Two and two groups should now merge so that the new groups have 200 dices. Let now six dots and five dots define the decayed state. Repeat the procedure in part 1 and make the corresponding graphs.

Question

Do your expectations turn out to be true?

Determination of the Boundaries of the Visual Spectrum

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the boundaries of the visual spectrum
Assumed knowledge	How to determine wavelength in an interference experiment



Equipment

diffracting grating (between 500 and 1500 lines pr mm)
overhead projector
white screen/wall

Procedure

Put a diffraction grating above the lens in an overhead projector and make a square of approximately $0.5\text{cm}\times 0.5\text{cm}$ using four opaque sheets on the overhead platform. Vary the opening of the square until you get as sharp and clear colors as possible.

Questions

1. Why do you get a collection of visual spectra, one for each fringe – except the zeroth?

2. Explain what is so special about the white zeroth fringe.

Data Analysis

Determine the approximate wavelengths of the red and violet parts of the spectrum by a meter stick and a bit trigonometry.

If your image is clear enough, try to determine the wavelengths of other colors.

Compare the results with theoretical values.

Drift Velocity on a Bed of Nails

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Model the movement of electrons in a metallic conductor

Equipment

A bed of nails
Stopwatch
Data analysis software with support for data fitting

Introduction by a demonstration

The bed of nails demonstration has been used to introduce the concept of pressure [1,2], to illustrate the difference between elastic and inelastic collisions [3] or to motivate the concept of distribution [4]. This demonstration simulates the drift velocity of free electrons in an electric circuit:

Make a plane of incline of the bed with the nails upwards. Place a small ball (diameter approximately half the characteristic spacing of the grid of nails) on the top and let it roll downwards. The analogy between the ball, the nails and the parallel component of the acceleration of gravity and respectively a free electron, the short range periodic potential of the metal atoms, and the electric field should now be clear. An extension with more balls simultaneously rolling down the plane would also indicate the possibility of electron-electron scattering in addition to electron-atom scattering.

Unit 1 – Data fitting

For each varying angles of the plane with the horizontal, determine the drift velocity.

Plot the drift velocity versus the parallel component of the acceleration of gravity.

Make a best fit in a data analysis software program and make an interprentation of each of the parameters you have determined. Remember Occam's principle!

Unit 2 – Review of Statistical Concepts

Keep the plane at a fixed angle and study the distribution of drift velocities by calculating measures of characteristic values and variability.

References

[1] PIRA demo number 1K30.10 at the website PIRA200, http://www.physics.ncsu.edu/pira/pira200.html.

[2] David P. Taylor, "A simple way to build a bed of nails," *The Physics Teacher* **34**, p. 227 (Apr. 1996).

[3] Manfred Buchner, "The bed of nails revisited," *American Journal of Physics* **56**, pp. 806 – 810 (Sep. 1988).

[4] Gerald L. Hodgson, "Weight distribution in a bed of nails sandwich," *The Physics Teacher* **13**, p. 52 (Jan. 1975).

Energy of a Freely Falling Body

Syllabus reference	2.9
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	Determine how the kinetic, potential and total mechanical energy varies with time

Equipment

A large ball
Motion detector

Procedure

1. Put the motion detector on the floor and hold a ball directly above the detector. When the motion detector runs, throw the ball directly upwards so that it reaches its maximum point after 10 – 15 cm. If you throw higher, any deviations from the vertical will probably be too large and the data will be poor.

2. Transfer the data to Graphical Analysis.

3. Choose ”Graph” from the menu and deactivate ”Connecting lines”. The data points are then plotted without lines joining them.

4. Next step is to produce 3 columns; one for potential energy, one for kinetic energy and one for total mechanical energy. To produce a new column you choose ”Data”, ”New column” and ”Calculated”. In the three empty boxes at the top you fill in column name (f.ex. Potensiell energi), column units (f.ex. J) and column definition (f.ex. 0.2*9.8*”L1”)(0.2 is the mass of the ball in kg and ”L1” is the displacement data, i.e. height above ground).

5. Plot one graph of potential energy vs. time, one graph of kinetic energy vs. time and one graph of total mechanical energy vs. time:

$$E_p = mgh \qquad E_k = \frac{1}{2}mv^2 \qquad E_t = E_p + E_k$$

6. Determine the best-fit linear model for the data of total mecanical energy vs. time. Use this to determine how much of the mechanical energy that is transformed into heat energy while the ball is in the air.

7. What is the interpretation of the slope of the linear model in part 6?

Energy of a Rolling Wagon

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Plane of incline
A rolling wagon
Motion detector
Meter stick

Pre-Lab Questions

Under what circumstances is the mechanical energy conserved for a rigid body?

Procedure

Design an experiment that investigates to what extent the total mechanical energy is conserved for a rolling wagon on a plane of incline, starting from rest.

Post-Lab Questions

Give reasons for any deviations from conservation of the total mechanical energy.

Falling Coffee Filter

Syllabus reference	2.2
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	
Aim	Determine the air resistance acting on a falling coffee filter.

Equipment

Coffee filter
datalogger
motion detector
calculator
Graphical Analysis

Pre-Question

If the air friction on an object is proportional to the square of the speed, show that a body in free fall will obtain a terminal velocity proportional to the square root of the mass of the body.

Procedure

1. Put the motion detector on the floor and hold a coffe filter directly above the detector. Measure now position vs time when the filter falls.

2. Use Graphical Analysis to make a velocity vs time graph. Determine the limiting speed.

3. Repeat now part 1 and 2 for 2 filters together, 4 filers together and finally 8 filters together.

4. Determine the mass of one coffee filter. How can you very easily improve the precision of this measurement if we assume that the filters have tha same mass?

5. Use the result of the pre-question to determine whether the air friction of the filter is proportioal to the square of the speed: Make a graph in Graphical Analysis of limiting speed vs square root of mass and make a judgement on whether the graph is linear.

Force Exerted by a Falling Chain

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the air resistance acting on a falling coffee filter.

Equipment

A paper drinking cup
A force sensor
Tape
A flexible chain

Set-up

The paper drinking cup is taped to the arm of the force sensor. Set up the probe to measure force with millisecond time resolution.

Pre-question

1. If the flexible chain is falling into the cup, how would the force vary as a function of time?

2. What happens to the force versus time graph when the complete chain has falled into the cup?

Experiment

Test your answers to the previous questions by doing an experiment.

Reference

Willem H. van den Berg, “Force Exerted by a Falling Chain”, The Physics Teacher, Vol. 36, Jan 1998, pp. 44 – 45.

Force of Buoyancy

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Investigate the buoyant force on an object as a function of the volume of the object.

Equipment

Force sensor
Metal cylinder with hook
String
Water
Oil (for the extension part)
Ruler

Procedure

According to Archimedes' law the force of buoyancy on an object wholly or partially submerged in a fluid is equal to the weight of the fluid displaced by the object. By hanging a metal cylinder from a force sensor and letting the cylinder be partially submerged within the water (depth h), the force of boyancy should increase linear with the depth.

Do this experiment.

Data Analysis

Make a linear best fit to a plot of force measured by the sensor as a function of depth.

Questions

What does the gradient of the linear plot say?

What is the meaning of the intercept with the second axis?

Extension

Repeat the data collection using vegetable oil instead of water.

How can you determine the density of the oil from the graph?

Forces Opposing the Motion of a Car

Syllabus reference	
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	Determine how the total force opposing motion on a car depends on the speed

Equipment

A car with a patient driver and at least two observers, stopwatch, Graphical Analysis

Security Risk

To avoid hazardous situations it is important that the driver focuses 100% on driving the car in a safe way and leaves the data collection to the observers.

Data Collection

1. Find a level, straight stretch of a road where the speed limit is 80 km/h.

2. Let the car enter this area with a speed of 80 km/h and disconnect the engine with the clutch so that the car is rolling until the speed is 20 km/h.

3. At the same instant the engine is disconnected, start the stopwatch. Record the time taken to reach the speeds listed in the first column in the table below.

Speed	Time	
v, [km/h]	**t, [s]**	
80		
70		
60		
50		
40		

30		
20		

4. To reduce the effect from wind and gravity (if the road is not 100% level) repeat the experiment on the same stretch, but now in the opposite direction. Record the data in the second column.

5. Find the total mass of the car included driver and passengers.

Data Analysis

1. Analyse the data with the aid of Graphical Analysis.

2. Determine the instantaneous acceleration for different speeds from the gradient of the graph. Use EXAMINE and Tangent line to analyse. Write down the values for acceleration in a table.

3. Use the acceleration data to compute values for the total force acting on the car. Find a mathematical model for the total force as a function of speed. (Plot the graph of F vs. v)

Friction of a Low-Friction Cart

Syllabus reference	
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	

Equipment

motion detector
plane of incline with variable gradient
low- friction cart

A Theoretical Result

If your teacher tell you to derive the result below, you should do so. In any case the result will be useful in your planning.

Assume that a cart moves on a plane of incline with angle θ with respect to the horizontal. When it moves down the incline the acceleration is a_d and when it moves up the incline the acceleration is a_d. Neglecting air friction, but assuming kinetic friction with corresponding coefficient μ_k, show by using Newtons second law parallel and normal to the plane that

$$\mu_k = \frac{(a_u - a_d)}{(a_u + a_d)} \cdot \tan\theta$$

Planning

Use the result above to design a procedure to find the coefficient of friction between the cart and the plane of incline. In particular, in your analysis of the data the coefficient should be determined as a slope in a diagram where two transformed quantities (which?) are plotted along the first and second axis.

Reference

R. F. Larson, *Measuring the Coefficient of Friction of a Low-Friction Cart*, The Physics Teacher, Vol. 36, Nov. 1998, pp. 464 - 465.

Heat Conduction

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Compare heat conduction of two metals (like Al and Cu)

Equipment

Thermometer and two temperature probes
Meter stick
Graphical Analysis
Two metal rods of 30 cm and with equal cross section
Beaker and hot water

Procedure

Attach the two temperature probes to the metals rods – one for each metal rod (20 cm from the end) and put the thermometer into a beaker of warm water of depth 10cm. When the temperature of the water is changing slowly (say 10K above room temperature), place the ends of the rods simultaneously in the beaker and measure temperature vs time.

Use the two temperature vs time graphs to compare the rates of heat conductivity for the different metals by comparing slopes.

Post-Question

How would you modify this experiment in order to test the dependence of conductivity on length and cross section?

Extension

Given two plates, one plastic and one metallic, and two identical small ice cubes. Simultaneously one cube is placed on the plastic plate and the other is placed on the metallic plate. Which cube will melt first? Make a prediction before you perform an experiment to test your answer.

Heat Transfer

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Purpose	Heat transfer of aluminium cans
Prior knowledge	

Part 1

If hot water is put into two identical aluminum cans, one unpainted and the other painted black, which can would you expect to cool down fastest?

Use temperature sensors to measure the temperature of the water in each can to test your hypothesis.

Questions for part 1

1. When the cans are cooling, which processes transfer heat?
2. Which process do you think is dominant?
3. When a can is cooling, it cools faster at the beginning. Why is this so?

Part 2

Empty the cans and make sure they have room temperature. Redo the experiment in part 1, but now with a fan blowing equally on each of the cans. Before you do the experiments, make a hypothesis on what you believe will be the changes of the graphs in part 1. Why should you be careful to place the temperature probes in a similar way on the two cans?

Questions for part 2

4. When the cans are cooling, which processes transfer heat to and from the cans?

5. Which process do you think is dominant? Why?

Part 3

6. Empty the cans and make sure they have room temperature. Redo the experiment in part 1, but now with the following modifications: The water filled into the cans is at room temperature and a heat lamp is placed near the cans in such a way that the cans are equally heated. Before you do the experiments, make a hypothesis on what you believe will be the changes of the graphs in part 1. Why should you be careful to place the temperature probes in a similar way on the two cans?

Questions for part 3

7. When the cans are heated up by the lamp, which processes transfer heat to and from the cans?

8. Which process do you think is dominant? Why?

Hooked on Strings

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Verify Hookes law by curve fitting in Graphical Analysis

Equipment

Meter stick
String
Weights
Graphical Analysis

Pre-Lab Questions

1. If your know the mass of an object, how do you find the force due to gravity?
2. What is the force due to gravity of a 23g object?
3. How do you convert from centimeters to meters?
4. What is 21.50cm in meters?

Procedure

1. Place the string vertically from a fixed point and put a weight on the free end. Write down the mass and the corresponding displacement of the string.
2. Repeat step 1 with other masses.
3. Use Graphical Analysis to make a best fit of the applied force on the string versus the displacement of the string.

Post-Lab Questions

1. In general, what pattern do you notice between the force due to gravity of the masses and the displacement of the spring?
2. What is the physical meaning of the slope for the force-displacement graph?
3. What is the physical meaning of the vertical intercept for the force-displacement graph?
4. What would be the force required to stretch the spring 10cm?
5. What would be the displacement of a 100g mass?

Hooked on Strings Revisited

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Combination of strings in parallel and in series

Equipment

Meter stick
String
Weights
Graphical Analysis

Pre-Lab Questions

1. How would you experimentally determine the effective spring constant when two springs with different spring constants k_1 and k_2 are connected in parallel?

2. How would you experimentally determine the effective spring constant when two springs with different spring constants k_1 and k_2 are connected in series?

3. Explain theoretically that in parallel we have an effective spring constant $k_{eff} = k_1 + k_2$ while in series an effective spring constant satify $\frac{1}{k_{eff}} = \frac{1}{k_1} + \frac{1}{k_2}$.

Procedure

Make a procedure to test the two formulas in the previous sections (Hint: For the series case analyze the inverse of the string constants: $\frac{1}{k_{eff}} = \frac{1}{k_1} + \frac{1}{k_2}$).

Post-Lab Questions

What formulas would you expect for the effective constants when you have three spring constants in series and in parallel?

How Fast is Your Index Finger?

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the maximum average speed of your index finger.

Equipment

Photogate timer
Meter stick

Procedure

In gate mode, a single photogate measures the time for which its sensing beam is blocked.

Use this fact with the equipment above to make a measurement procedure to determine the maximum speed of your index finger under the following conditions:

- You have to stay in your seat.
- Shoulder swings are not allowed, but elbow movements are allowed.

Acknowledgement

This lab is based on ideas from the article

John Gardner, "How Fast Is Your Finger? An Introduction to Photogate Use", The Physics Teacher, Vol. 41, March 2003, pp. 181 – 182.

Impulse

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Investigate if the change in momentum for an object is equal to the impulse given.

Equipment

TI-calculator with link cable and CBL, ultrasonic motion detector, student force sensor, wagon, tread with elastic band, tape, scale

Procedure

Use a screw holder to fasten the force sensor to the end of the table. Connect the tread with the elastic band to the wagon and the force sensor, so that the wagon is stopped by the tread when you push it along the table. The purpose of the elastic band is to increase the duration of the applied force.

Use tape to fasten the motion detector to the table 60 cm from the where the wagon stops, so that the detector will measure the distance to the wagon before, during and after the bounce.

Connect both the motion detector and the force sensor to the CBL. Fasten a bit of cardboard to the wagon to improve the reflection of the sound pulses from the detector.

Data collection

The force sensor must be calibrated with the appropriate procedure provided in the PHYSICS program on your calculator. Set up the probes with 0.02s between the 100 samples, which give the experiment a total length of 2s.

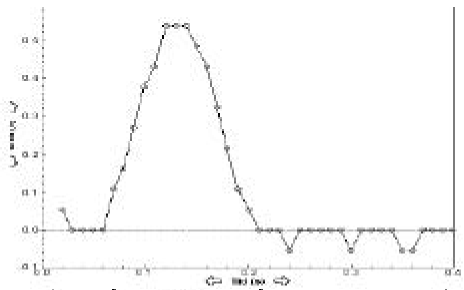
Start the data logger and put the wagon into motion towards the motion detector immediately. Try several times until you get a graph with maximum around t = 1s.

Determine the mass of the wagon.

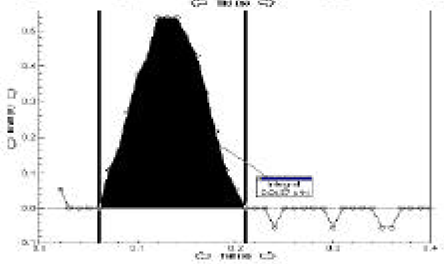
Transfer your data to Graphical analysis (only L1(time), L2(force) and L4(position)).

Repeat the experiment so everybody on your group gets their own data to analyse.

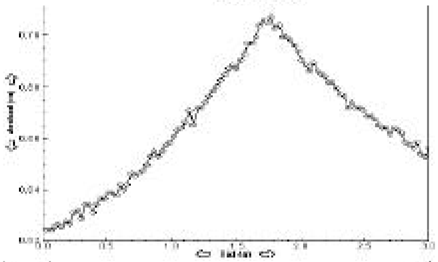
Data Analysis



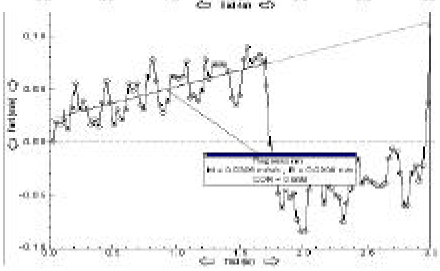
Plot a scatter diagram of the force versus time (remember to use correct quantity symbols and units).



Find the impulse from the area under the graph (mark the area and use integral from the analyse menu).



Plot a scatter diagram of the position as a function of time.



Find the velocity of the wagon just before and after the bounce (a helpful hint: let the marking of the area still be on when you change from the force to the position graph.). To find the velocities you could either use the tangent line from the analyse menu or you could fit linear curves to the points in question.

Use these results to find the change in momentum for the wagon. Compare this to the impulse found earlier.

Questions

Which other forces act on the wagon during the deceleration of the wagon?
How would these forces affect the value for change in momentum?

How would the force-time graph look like if you only used the tread without the elastic band?

Will the tens ion measured by the force sensor be the same as the tension acting on the wagon?

Impulse Revisited –
Air Bag Collision Competition

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Students determine the impulse of collisions with different "air bags" that they create themselves.

Equipment

Air Bag Materials
Force Sensor
Motion Sensor

Rules of the Game

Each group has to supply materials that will serve as an air bag for the carts on the air track according to the following rules:

1. Bumper must not impede acceleration
2. Balloons may not be used
3. Bumper must hit force probe directly
4. Bumpers must be designed to attach to front of cart readily
5. Bumper must not destroy probe
6. Each group are allowed maximum 3 trials for modifications
7. The angle of inclination of the air tracks is the same.
8. The carts should start at the same position on the air track from rest

The winning team is the team with the largest percentage drop in impulse from a collision without the air bag to a collision with the air bag.

Questions

1. Draw qualitative force diagrams for each of the two collisions.
2. In what direction is the force and acceleration? Explain.
3. Which collision produced the greatest force? Explain.
4. Which collision took the longest amount of time? Explain.
5. Why do air bags save lives? Explain using terms such as force, time, impulse, change in momentum, etc.

Kepler's Third Law with a Graphical Calculator

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine Kepler's Third Law

Equipment

Graphical Calculator

Data

Table I. Radius and period of planets.*

Planet	Radius (R) of orbit of planet in A.U.	Period (T) in days
Mercury	0.389	87.77
Venus	0.724	224.70
Earth	1.000	365.25
Mars	1.524	686.98
Jupiter	5.200	4332.62
Saturn	9.510	10,759.20

*Source: Physical Science Study Committee, *Physics* (Heath, 1960), p. 350.

Procedure

The exact procedure will vary with the kind of graphical calculator you have, but the following instructions for TI-83 Plus should give you an idea of what you should do on your graphical calculator:

1. Put the radius data in list L1 and the corresponding period data in list L2. — STAT/EDIT

2. Do a power regression — STAT/EDIT/A:PwrReg L1 L2

Reference

James Metz, *Finding Kepler's Third Law with a Graphing Calculator*, The Physics Teacher, Vol. 38, Apr. 2000, p. 242.

Kinetic Coefficient of Friction

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Plan an experiment to determine the kinetic coefficient of friction between two surfaces.

Equipment

Motion detector, board, a block, stand with clamp, meter stick

Theory

Show that for an object sliding down an inclined plane with constant velocity the kinetic coefficient of friction may be found from the simple relationship $\mu_k = \tan\alpha$ where α is the angle of the incline to the horizontal.

Procedure

Together with 2 fellow students, develop a procedure to measure μ_k for at least 5 different combinations of materials. Care should be taken to minimize uncertainties and errors.

Evaluation

Every group hand in one example of the plan in the start of the period. The experiment is carried out according to the plan. Any changes done are noted carefully by each student.

Every student hands in a report with the results of the experiment together with a personal evaluation of the procedure.

Latent Heat of Fusion of Water

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in Aim	Determine the latent heat of fusion of water.

Equipment

Ice, beaker, temperature probe
Bunsen burner
Water
Stop watch

Procedure

1. Fill the beaker with water and put the beaker on the stand.

2. Ignite the Bunsen burner and adjust the flame such that it is sharp and blue.

   NB! This particular flame condition should be the same in all the experiments below.

3. Measure the temperature as a function of the time every tenth second for a total of 3 minutes. Stir throughly with a stick.

4. Empty the water out of the beaker, put a large piece of ice into the beaker, and measure the time it takes to melt the ice. Stir the ice with a stick.

Data analyse

1. Calculate the effective amount of energy per time the water in the beaker receives per time.

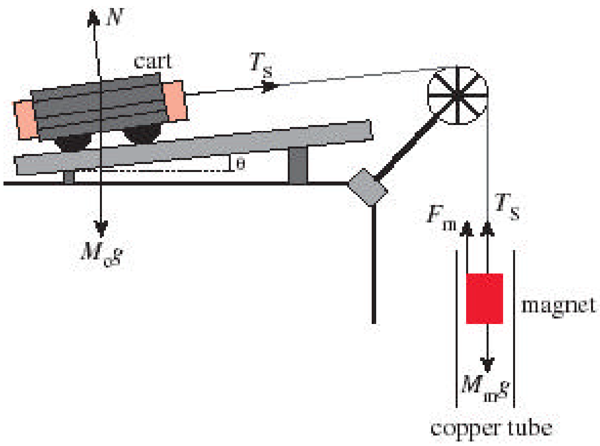
2. Use the time in part 1 to estimate the heat of fusion of ice.

Questions

1. Why is it so important to stir during the measurements?
2. Why is the energy per time in part 1 of the data analysis called effective?
3. Why should the flame condition be the same?

Lenz's Law

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in Purpose	Predict and verify/falsify final temperature when mixing water of different temperature and mass.
Prior knowledge	



Use the figure above to design an experiment to test the dependency of the magnetic force on the speed.

Before you plan and do the experiment you need the following observation: When the magnet falls inside the tube, eddy currents are generated that opposes the motion (Lenz's law). Thus the magnet will quickly achieve a constant speed. Use Newtons second law under these conditions to show that we have the relation $F_m = (M_m - M_C \sin\theta) \cdot g$.

Magnetic Field Strength of a Permanent Magnet

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the strength of the magnetic force as a function of distance.

Equipment

Magnetic Field Sensor
Permanent neodymium Magnet
meter stick

Unit I

Put the Magnetic Field Sensor so the end of the rod is even with the zero end of the meter stick. The north pole of the magnet is then placed parallel to the ruler facing the sensor next to the meter stick. Measure the axial field strength in steps of 0.5 cm along the ruler until you observe no change as the distance changes.

Make a best fit to a power law on your favourite data analysis software.

Unit II

Make a new series of measurements with the following change in unit I: The north pole of the magnet and the sensor rod is now placed normal to the ruler.

Make a new best fit to a power law on your favourite data analysis software.

Questions

- Does the magnetic field strength decrease as a function of distance in the same way?
- What would the results have been if only the orientation of the magnet had been changed, i. e., the orientation of the sensor remained the same?

Mixing Liquids

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Predict and verify/falsify final temperature when mixing water of different temperature and mass.

Equipment

water
temperature sensor

Pre-Questions

1. Suppose you are given two containers with water. The first container contains water with mass m_1 and temperature T_1 while the second has water of mass m_2 and temperature T_2. Derive a formula for the final temperature of the mixed water.

Suppose you are going to do an experiment corresponding to the problem in the previous question.

2. Why is it better to start with temperatures above and below room temperature rather than both temperatures above or below room temperature?

3. Why should you stir thoroughly to mix the water?

Experiment

Plan, execute, and evaluate an experiment that test the predictions of the formula you derived in pre-question 1.

Modelling Projectile Motion

Syllabus reference	2
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	

Equipment

Two metal rods
Sticky tape
weights
string

Procedure

Let one metal rod be vertical and one rod normal to the first rod. Divide the rod into five sections, where each section has a weight hanging from it via a string.

The distance along the horizontal antenna is supposed to be proportional to displacement along the horizontal direction and the string length is proportional to the vertical displacement after 1s, 2s, 3s, 4s, and 5s.

Document your model with a digital image and write in your report how you determined the horizontal and vertical lengths. State clearly the scales between model length and real motion length.

Questions

On the moon, the acceleration of gravity is approximately one sixth of the earths acceleration of gravity. How would your models look like for motions on the moon?

Reference

Sean Cordry, “Projectile Motion Model”, The Physics Teacher, Vol. 41, Oct. 2003, pp. 430 – 431.

Momentaneous Velocity

Syllabus reference	2
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	Determine how the momentaneous velocity of a rolling wagon on an incline varies with time (velocity/time graph) for various angles of incline.

Equipment

Rolling wagon
CBL2
Motion detector probe

Procedure

Use your table as an incline and your chair to adjust the angle of incline. For the various angles a determine the slope of the velocity/time graph, assuming it to be a linear function.

Repeat this measurement for various angles a.

According to theory, assuming no friction, the acceleration of the wagon depends on a as $a = g \sin a$. Make a best fit of acceleration a vs. $\sin a$ to check this prediction.

More Student Motion

Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	
Aim	Investigate motion of students

Equipment

Motion sensor and/or acceleration probe (at least 20 points/sec.)

Overview

The aim of this lab is to graph acceleration vs time and velocity vs. time of a sprinting student. The students form groups of 2 – 3 in the schoolyard and make measurements of motion of one student in their group with the sensor(s)

Data collection

Phase 1	Each student on the group is sprinting away from the motion sensor.
Phase 2	Do the same as in phase 1, but now with an acceleration probe.

Data analysis

For phase 1	Make a graph of position vs. time for each movement. Using a data analysis program (like Graphical Analysis), make also a velocity/time and acceleration/time graph.
For phase 2	Make a graph of acceleration/time for the acceleration probe. If your data analysis software allows you to integrate, find also velocity/time graph. Compare velocity/time graphs and acceleration/time graphs in phases 1 and 2.

Extension – Student power

The aim of this extension is to determine the horsepower rating of students running up a flight of stairs. Each group has to measure the vertical distance up stairs and the time needed for each member to run up the stairs. By measuring the weight at home, each student has enough information to calculate his/her personal amount of horsepower (1 horsepower is approximately 746 Watt).

Read the electrical kilowatt-hour meter at home during a period of at least 24 hours. Compare this reading with your own power.

Why do we measure the vertical height, not the distance up the stairs?

Reference

James H. Nelson, *Student Power*, The Physics Teacher, **10** (Dec. 1972) p. 529.

Nuclear Activity vs Distance

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Investigate the relationship between the distance to a radioactive source and the measured activity from the source

Equipment

Nuclear activity sensor
Radioactive Sources (alpha, beta, gamma)
Meter stick

Procedure

For each source measure the activity of the source with the nuclear activity sensor vs the distance from the sensor to the source.

Data Analysis

Make a best fit of activity vs distance to a power function pluss a constant on your favourite data analysis software.

Questions

Why should you add a constant to the power function when fitting activity vs distance? What does the constant represent?

Does alpha, beta, and gamma radiation follow the inverse square law?

Is there any characteristic difference between the three sources?

What additional measurement should you do in order to analyze the data by an old-fashoned log/log plot?

Ohms law

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Verification/falsification of Ohms law

Equipment

Your choice!

Procedure

Design an experiment where the data analysis is done by a linear best fit in either Excel or in Graphical Analysis. The resulting graph should put you in position to verify/falsify Ohms law for two different resistors:

- Light bulb
- Ordinary resistor

Oil Pollution

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Purpose	Data analysis

Equipment

Oil, water, large container, and drop counter.

A theoretical challenge

Imagine a leak from a pipe submerged under the sea, close to the surface. As a result the area of the escaped oil is approximately the area of a circle with an increasing radius.

If the thickness of the area is approximately constant and the pipe leaks a constant amount of oil per unit time, explain why the radius should increase proportional to the square root of time.

Experimental procedure

Test the hypothesis above by dropping oil drops at the same spot on a large surface of water. Measure the radius versus the number of oil drops.

Analysis

1. Make a graphical fit on Graphical Analysis or Excel
2. Make a transformation of one of the variables so that if the hypothesis is true, a linear graph should appear.

Question

If the radius become large, is it resonable that the thickness of the oil film will remain constant? Explain your reasoning.

Reference

Eduardo E. Rodriguez, “A Proposal for Experimental Homework”, The Physics Teacher, Vol. 36, Oct. 1998, pp. 435 – 437.

Parallax Measurement Competition

Syllabus reference	F.2
Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	One week after delivered out
Aim	The aim of this activity is understand how distances (below 100ly) to stars can be measured by the parallax method.

Equipment

Right hand thumb
Right and left eye
Wall
Ruler
Spreadsheet

Measurement procedure

In this competition the students are divided into teams (four?). In front of a certain wall at a particular distance as given by the teacher, each member of the team is going to determine the approximate distance from their face to their thumb according to the procedure below (steps 1 to 6):

1. Ask a comember to measure the distance between the center of your right eye and the center of your left eye with a ruler.

2. With the left eye closed, keep your right hand thumb at an arms length in front of you. Notice the position of the thumb on the wall. Close the right eye and notice how many thumb widths the position of the right hand thumb on the wall has changed. Assuming that a thumbs width is one degree, estimate how many degrees the thumb has changed its position.

3. Use the results in steps 1 and 2, a simple drawing and a bit trigonometry to estimate the distance from your face to your right hand thumb. This picture and your calculations should be part of your delivery.

4. Ask a comember to measure the distance between your face and your right hand thumb with a ruler.
5. Determine the relative error when comparing steps 3 and 4.

6. The team with the least average relative error has won.

All calculations in the steps 1 to 6 above should be clearly presented on a spreadsheet. A print-out should be included in your report.

Questions that should be answered in your data analysis

7. In the simulation above what correspond to "the fixed stars", "a nearby star", "the position of the earth in January" and "the position of the earth in June" of right eye open, wall, right hand thumb and left eye open?

8. At a solar system distance scale, a line of length 1 AU subtends an angle of one arcsecond at a distance of one parsec. What basic distance ("facesec") would correspond to an angle of one arcsecond in your case?

Penetration of Nuclear Radiation

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Purpose	Investigate the penetrating ability of three common types of nuclear radiation
Prior knowledge	

Equipment

Nuclear Sensor,
Radioactive Sources (alpha, beta, gamma)
Shielding material (lead squares, paper squares, plastic squares)

Procedure

1. Determine the background activity (use at least two minutes).
2. For the alpha source, put one lead square on the top of the source and measure the activity directly outside the square. Do the same measurement with two, three, four, and five squares on the top of each other.
3. Repeat the previous experiment with paper and plastic squares.
4. Repeat the three previous experiments for the beta and the gamma sources.

Data Analysis

Make a graph of activity vs number of squares for all combinations of source and shielding material. If there is good enough data, make a best fit to an exponential decay.

Questions

1. Order the sources in decreasing penetrating ability. Why is there a difference in the penetrating ability of the three basic radiation types?

2. What does the results tell you about the ability of different materials to absorb the energy associated with nuclear radiation?

3. According to conservation of energy the absorbed radiation energy must be transformed to another kind of energy. What kind of energy would that be? Can you imagine an experiment to verify your suggestion?

4. What effect has the thickness of the shielding material on the count rate?

5. What effect seems the density of the shielding material to have on the count rate? Predict the relative efficiency of air vs water in stopping radiation.

Period of a Harmonic Oscillator

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Purpose	Measure the motion of a mass moving up and down on the end of a spring.
Prior knowledge	

Equipment

masses
springs
motion sensor
rod (for supporting the verical hanging spring)
square of stiff paper with small area (increases area of reflection of waves from motion detector)

Experiment 1 – Vertical Case

According to theory a harmonic oscillator with mass m and spring constant k has a period of oscillation $T = 2\pi\sqrt{\frac{m}{k}}$.

- Use dimensional analysis to show that this equation make sense.
- Transform this formula to a new formula so that the new formula is on a linear form.
- Plan, execute, and evaluate an experiment that test the transformed formula using the equipment under the heading Equipment. The movement should be vertical.

Experiment 2 – Horizontal Case

An alternative procedure is to use a horizontal air track with a wagon connected to both ends with two springs of equal spring constant. Do the corresponding experiment here without the motion sensor by measuring the interval of time for a large number of oscillations with an

old-fashioned analog clock.

Phases and Phase Change

Syllabus reference	3.2.5
Assessment Criteria	Data Collection, Data Processing and Presentation
Date delivered out	
Date for handing in	
Aim	Determine the melting point of vax and investigate changes of phase

Equipment

Temperature probe
Cup with wax
Heater
Bunsen burner

Experimental procedure

1. Heat up the wax until all of it has become liquid.

2. Remove the burner.

3. Put a temperature probe into the liquid phase of the wax. Do not let the probe touch the bottom of the cup (why not?).

4. Measure the temperature of the vax every half minute as it cools down.

Data analysis

1. Make a graph of temperature vs. time. Determine the melting point of Wood's metal from the graph.

2. For temperatures different from the melting temperature, the heat rate from the metal to the environment at any given temperature will be proportional to the gradient of a T/t-graph. Why?

3. What does the diagram tell you about the heat rate near the melting point as opposed to longer away from it?

Pink and White Noise

Syllabus reference	4
Assessment Criteria	Data Collection, Data Processing and Presentation, Conclusion and Evaluation
Date delivered out	
Date for handing in	
Aim	Beside getting a qualitative understanding of power spectra the aim is to demonstrate how it is possible to measure characteristics of nonharmonic waves by Cooley-Tukey fast Fourier transform.

Assessment criteria

Planning A: Based on the theory in the section Theory below, what kind of power spectra do you expect from the three sources given in the section Experimental Procedure ?

Evaluation: Evaluate your planning

Equipment

TI Calculator with PHYSICS program
CBL with michrophone probe
Radio
Running water
A sealable box

Theory

A pure sinusoidal wave with a definite frequency and amplitude is an extreme idealization of most waves. In stead a "real" wave will consist of many (even infinite) number of sinusoidal waves, each with its own frequency and amplitude. The power, energy pr time, radiated from a source will therefore in general get different contributions from different frequencies. The plot of the power versus frequency for a given wave source will then give information about the composition of the various sinusoidal waves from the source - the power spectrum. Beside beeing a standard technique in acoustics and electromagnetism, the large scale matter distribution of the universe itself has recently been studied successfully in this way[1].

1Stephen D. Landy "Mapping the Universe", Scientific American June 1999 pp 30-37.

We will in this investigation consider only two[2] characteristic power spectra of backgroud noise: pink and white noise. White noise[3] is a source with a power spectrum where all frequencies contributes equally (think by analogy to light: if all frequncies are present we obtain white light). Therefore the power spectrum is a horizontal line. For pink noise the power spectrum is inverse proportional to the frequency and therefore the lowest frequencies contribute most.

Experimental procedure

Each group member should collect one sample of data from each of the three following sources:

1. A badly tuned radio
2. Running water
3. "No source" - i. e. microphone placed in a sealed box

Data analysis

For each of the data samples the following analysis should be done in Graphical Analysis:

First of all we want the amplitudes and frequencies of the harmonic waves:

1. Copy the data set from your calculator to Graphical Analysis.

2. Plot a graph of the amplitudes of harmonic waves versus their frequencies by choosing the menue command *Window/New Window/FFT Graph*. The result is two new coloumns in the data window, frequency and amplitude.

We want now to display the power spectrum, but due to a bug in the program we can't neither selecting the frequency coloumn along the first axes nor define a derived coloumn based on any of these two new coloumns. Therefore we have to do this plotting in a more cumbersome way:

3. Copy the resulting two coloumns by first selecting them in the data window, then applying the command Edit/Copy Data.

4. Get a new working area by selecting File/New. Answer no to the question of saving the old file.

5. Select the x and y coloums and paste the data by the Edit/Paste Data.

6. Make a new coloumn called "Prop power" (proportional to power) and define it to be equal to the square of the amplitude coloumn.

[2] Brown noise, characteristic for brownian motion and with power spectrum inversely proportional to the square of the frequency, will not be considered.
[3] Also called Johnson noise.

7. By choosing the axes plot "Prop power" versus frequency.

8. Use the Analyze menue to check whether the graph or a portion of it (in that case take note of the boundaries of the region) can be considered on the form y=b (white noise) or on the form y=1/x (pink noise).

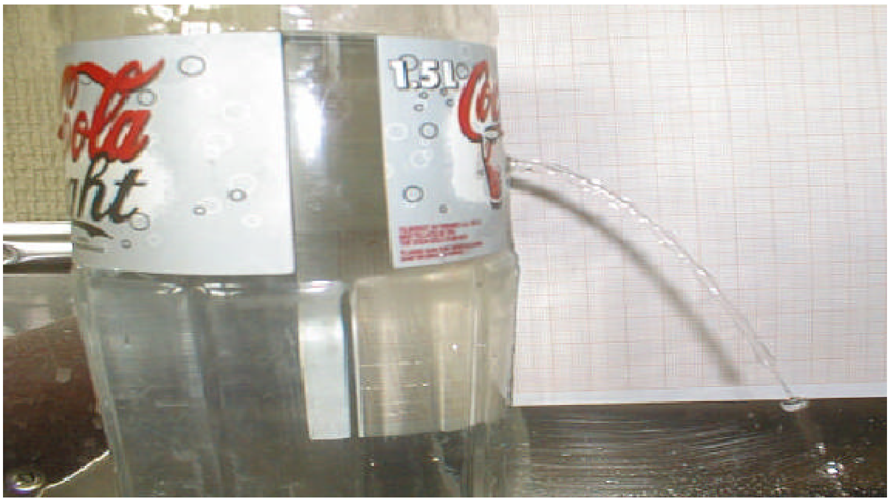
References

P. Bloomfield, *Fourier Analysis of Time Series: An Introduction*, Wiley 1976
Hida, Kuo, Potthoff and Streit, *White noise: An Infinite Dimensional Calculus*, Kluwer 1993
B. B. Mandelbrot, *Multifractals and* $\frac{1}{f}$ *noise: Wild Self-Affinity in Physics*, Springer 1998
M. Schroeder, *Fractals, Chaos, Power Laws: Minutes from An Infinite Paradise*, Freeman 1991
Ed. N. Wax, *Noise and Stochastic Processes*

Projectile Motion with Water

Syllabus reference	
Assessment Criteria	All
Date delivered out	
Date for handing in	
Aim	Investigate the projectile motion of water

Equipment



Soda bottle
Water
Digital camera
mm sheet

Problem

Water particles are streaming horizontally out of a soda bottle wall through a little hole. By choosing a coordinate system with the origin in the hole, show theoretically that all the particles will follow the same path and that this path is a parabola on the form $y = \frac{g}{2v_x^2} \cdot x^2$.

Design an experiment that investigates whether the quadratic form of this formula is correct.

Reference

Section "M-90. Water-Stream Parabola" in ed. Richard M. Sutton, *Demonstration Experiments in Physics*, McGraw Hill, New York 1938.

Refresh Frequency

Syllabus reference	2.2
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	
Aim	Determine the refresh frequency of a computer monitor and a light source.

Equipment

Computer Monitor - CRT
(This experiment will not work on an LCD or on a flat panel display such as a laptop)
Light intensity probe
Light bulb

Procedure

1. Set up your light probe with a least 120 (preferable much more) samplings per second and with a total sampling time of 0.1 seconds.

2. Hold the sensor against the screen and measure the light intensity

3. Plot the data and determine the period and thus the frequency.

4. Compare the result in part 3 with the frequency settings of your operating system (In Windows click the *Start* button on your desktop, then *Settings/Control Panel/Display*, then the *Settings* tab).

5. Change the frequency setting of the computer (Windows: see part 4) slightly and redo the experiment.

6. Make a measurement of a fluorescent light source in the ceiling and thus determine the AC line frequency (Hint: the light bulb has two maxima of light intensity during one cycle).

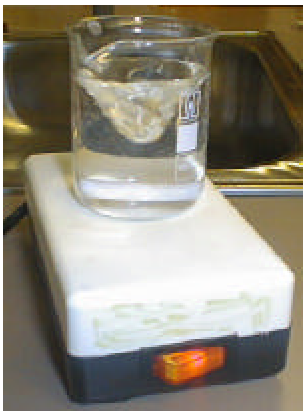
Questions

1. Use the frequency of the computer to calculate the time period between to cycles of your PCs processor. How far has a light signal travelled during this time interval?

Rotating System of Reference

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Study rotating frames of reference

Equipment



magnetic field switcher with rod magnet (chemistry lab)

beaker

water

digital camera

Procedure

Put the magnet into the beaker and fill ¾ of the volume with water. Place the beaker in the middle of the magnetic field switcher.

Turn on the switcher. When a stable surface of revolution has emerged, take a close picture of the surface from the side. Write down the angular velocity and take pictures for other velocities.

Data Analysis

Explain the form of the parabolic surface of revolution by considering a water particle on the surface from the point of view of

- the laboratory (inertial) frame of reference
- the rotating frame of reference

In particular draw the directions of the effective acceleration of gravity as measured locally by a comoving observer on the surface at two different points.

Where will the comoving observer measure the magnitude of the effective acceleration to be at a minimum/maximum?

Extension (optional)

Derive a formula for the surface of revolution.

Rutherford Scattering

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Simulate Rutherford scattering

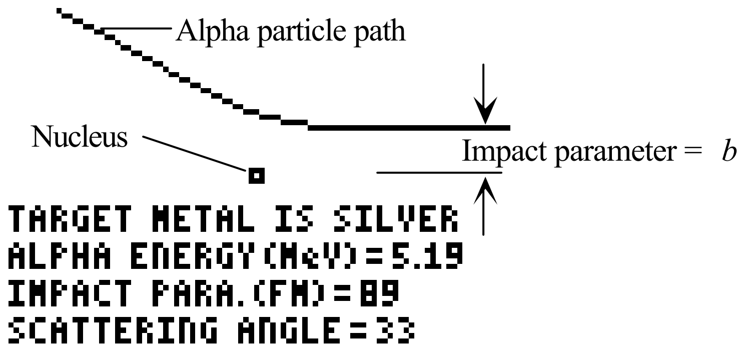
Equipment

TI82/83 Calculator
The file **ruthscat.zip** (downloadable from the archive http://www.ticalc.org/search/)

Procedure

Run the “RUTHSCAT” program on a TI-82 or a TI-83 calculator. In this simulation one of three metals (Gold, Silver, Copper) can be used as well as one Unknown metal.

A Single scattering event or Multiple scattering events can be displayed by the simulation. If a single scattering event is chosen, the “impact parameter” in femtometers (x 10–15 m) must be supplied. The impact parameter is the distance that the alpha particle is from a path that would deflect it straight back from the nucleus (see diagram below).



Independent of the scatter type (Single or Multiple), the alpha particles energy in MeV must be supplied. The alpha particles energy must be between 2 and 9 MeV for the simulation.

Rutherford Scattering Questions

1. In Rutherford's experiment the target metal was gold and the alpha particles had a kinetic energy of 4.48 MeV. What force causes the scattering of the alpha particles as they approach the gold nucleus? How does the strength of this repulsive force vary with the distance the particle is from the nucleus?

2. With a silver target metal and the alpha particle energy constant at 6.30 MeV, what is the effect of various impact parameters on the scattering angle? What causes such an effect?

3. With a copper target metal and the impact parameter constant at 85 fm, what is the effect of various alpha particle energies on the scattering angle? What causes such an effect?

4. With the alpha particle energy at 5.0 MeV and the impact parameter at 35 fm, what is the effect of various metals on the scattering angle? What causes such an effect?

The closest an alpha particle can get to a nucleus is called the "distance of closest approach" (D). The impact parameter (b) and the scattering angle (θ) are related to this distance by the equation $D = b\tan(\theta/2)$. The closest an alpha particle can get to the nucleus also depends on the alpha particles charge (q1) and energy (in joules not MeV) and the charge on the nucleus (q2). From conservation of energy, the kinetic energy of the incident alpha particle is converted to electric potential energy around a point charge, $E_k = (kq_1q_2)/R$. Here the variable R is the same as the distance of closest approach.

5. Choosing an unknown metal and a single scattering event, determine D and the charge on the unknown nucleus (qnucleus). Since the nucleus contains an integer number of protons, determine the number of protons in the unknown nucleus and theorize which element it was.

Acknowledgement

This simulation is a formatted version on the Word document (by an anonymous writer) that is included in the zipped file **ruthscat.zip**.

Simple Harmonic Motion

Syllabus reference	4
Assessment Criteria	Data Collection Data Processing and Presentation
Date delivered out	
Date for handing in	One week after delivered out
Aim	The aim of this investigation is to graph displacement, velocity, kinetic energy, potential energy and total energy vs. time

Equipment

CBL
Motion detector
Stand
Mass and spring

Measurement procedure

1. Use the motion detector to obtain a displacement-time graph. Plot the graph in the coordinate system below.

2. Use the motion detector to obtain a velocity-time graph. Plot the graph in the co-ordinate system below:

4. Plot the displacement-time graph and the velocity-time graph in the same co-ordinate system:

5. Use the velocity-time graph to sketch kinetic energy vs. time:

6. Assuming that the total energy remains constant sketch total energy vs. time, and use conservation of energy to sketch potential energy vs. time:

7. Try to find a mathematical model for the displacement as a function of time.

   Model : x =

8. Try to find a mathematical model for the velocity as a function of time.

   Model : v =

Extension

Let each student in the group do push-ups for ten seconds (as fast as possible) while a motion detector above her/his head is measuring the movement of the head. Determine which student has the least period.

Reference

Saffar Arjmandi, Joseph G. Brinkman, and Terrence P. Toepker, *Physical Push-ups*, The Physics Teacher, Vol. 41, Sep. 2003, pp. 323 – 324.

Simple Planar Pendulum

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

A data analysis software program
The rest is up to you :-).

Prelab work

Use your textbook or a search engine on the web to find the definition of a planar simple pendulum.

Make a hypothesis on which factors might influence the period of a simple planar pendulum. Use this hypothesis to design a measurement procedure that may falsify your claim.

Group work

In each group review the work done by the members on the prelab work. Use this to reach a consensus on what factors you will study and what procedure you will follow. If you have a question, ask your resourceful teacher :-).

Data collection

Do the procedure you developed in the group work.

Data Analysis

Use a data analysis software program to test your hypotheses.

In particular, make the following graphs in addition to graphs used to test your hypotheses:

1. a graph showing length of the pendulum versus the square of the period in SI units.

2. a graph showing length of the pendulum versus the square of the period where the length is measured in inches (1m = 39.4in) and the time in seconds.

For the latter two graphs determine the linear best fit. Find the gradient and the intercept with the second axis in each case. Please comment the results.

Acknowledgement

Keith Clay, *The Pendulum, Gravity, and that Number "9.8"*, The Physics Teacher, Vol. 42, Jan. 2004, pp. 14 – 15.

Simple Planar Pendulum

The reason for making a graph in the non-SI system of units is the following interesting numerical coincidence:

$$1\text{m} = 39.4\text{in}$$
$$4\pi^2 \approx 39.5$$

Since the length of the simple pendulum L as a function of the period T varies according to the formula $L = \frac{g}{4\pi^2}T^2$, the gradient in the non-SI units will with a good procedure be numerically close to 9.8. Some students will then jump on the conclusion that the gradient represents the acceleration of gravity, forgetting to ask themselves what the unit is.

The next page consists of exercises that can be used as a starting point on what the gradient represents.

Physics Lab Follow-Up

Simple Planar Pendulum

Exercise 1

1. The acceleration of gravity in the SI system of units has the numerical value 9.8. What is the corresponding unit of measurement?

2. Use the fact that 1m = 39.4in to find the numerical value as well as the unit of measurement for the acceleration of gravity in the non-SI system consisting of inches and seconds.

Exercise 2

The length L of the simple planar pendulum as a function of the period T varies according to the formula $L = \frac{g}{4\pi^2}T^2$ when the friction of air can be neglected and the initial angle from the vertical is small.

1. Calculate the numerical value of the gradient $\frac{g}{4\pi^2}$ in the SI system. What is the unit?

2. Calculate the numerical value of the gradient $\frac{g}{4\pi^2}$ in the non-SI system. What is the unit?

3. Compare the gradient in the SI system with part 1 of exercise 1: Can the gradient be considered to be the acceleration of gravity?

4. Compare the gradient in the non-SI system with part 2 of exercise 1: Can the gradient be considered to be the acceleration of gravity?

The moral that can be drawn from these exercises is: If you want to compare numerical values, you have to stick to the same system of measurement.

Specific Heat Capacity of Water

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Determine the specific heat capacity of water by an electric heating coil.

Equipment

CBL2
Temperature Probe
Old Calorimeter (insulating container: thermos)
Water
Heating coil
Voltage source
Clock

Review of Theory

If there is a voltage *V* over the coil and if the coil has resistance *R*, then during a time interval t the coil transfers the amount of heat $Q = \frac{V^2}{R} \cdot t$. If this coil is put into a beaker with water where the water has mass m_w and specific heat capacity c_w, during a certain interval of time *t* the temperature will increase ΔT

According to the law of conservation of energy the heat gained by the water must be equal to the heat lost by the coil. We have therefore $\frac{V^2}{R} \cdot t = m_w c_w \Delta T$ or $c_w = \frac{V^2 t}{R m_w \Delta T}$.

Measurement procedure

1. Measure and record the mass of the beaker empty.

2. Fill the beaker with just enough water so that the coil is covered in the old calorimeter (see frontal picture). Measure and record the mass of the beaker and water.

3. Put one of the thermal coils into the calorimeter. Please check that the wires are connected as shown in the table below.

4. Put the thermometer into the calorimeter.

5. Clock the time *t* for the smallest resistor with $12V$ over it to increase the temperature 5K.

6. Assuming the resistance is as given in the table below (depending on whether there is a green or a yellow-red button on it), determine the specific heat capacity of water.

Coil number 1 **Yellow-red button**		Resistance R=2.6Ω
Coil number 2 **Green button**		Resistance R= 2.1Ω

Table 1. Various resistances of the heat coils

Specific Heat of a Solid

Syllabus reference	3.2
Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	One week after delivered out
Aim	Determine the specific heat of a solid. Another aim is to be acquainted with the properties of a calorimeter, and the theory relating to its use.

Equipment

CBL2
Temperature Probe
New Calorimeter (insulating container: thermos)
Beaker
Water
Any uniform object with maximum linear dimension 4cm

Review of Theory

To measure the specific latent heat of a substance, we use the fact that no heat is exchanged between the objects inside an ideal calorimeter and the surroundings. The sum of all the thermal energy gains inside the calorimeter must be zero. If the objects include water, a solid body, and the calorimeter lining, then we have

$$m_w c_w \Delta T_w + C\Delta T_l + m_o c_o \Delta T_o = 0$$

where m is the mass, c is the specific heat capacity, C is the heat capacity and $\Delta T = T_f - T_i$ where T_f and T_i are the final and initial temperatures respectively.

Measurement procedure

7. Determine whether the object you have chosen will be completely submerged by 200mL of water inside your calorimeter. If this is not the case, use more water and keep track of how much you have used.

8. Place your object into a beaker containing water at room temperature. Let it rest there for at least 5 minutes so that its temperature comes to equal the temperature of the water. Meanwhile, do part 1.

Part 1 – Determine the heat capacity C of the calorimeter

3. Determine the initial temperature of the calorimeter lining by placing the CBL sensor tip inside the calorimeter for a few minutes with the lid on. Record this temperature.

4. Heat 200mL of water to roughly 60ºC. Turn the flame off and measure the temperature. This is the initial temperature of the water. Record this temperature.

5. Pour the water into the calorimeter and place the lid on top. Insert the temperature probe into the lid so that it is measureing the water temperature. Wait 3-5 minutes and record the temperature. This is the final temperature of <u>both</u> the calorimeter lining and the water. Record this temperature. Do not pour the water out!

6. Calculate the heat capacity of the calorimeter lining using that heat capacity for water is approximately 4200 Joules per Kelvin per kilogram:

$$m_w c_w \Delta T_w + C\Delta T_l = 0$$

Part 2 – Determine the specific heat capacity *c* of your object

7. Record the initial temperature of the object by measuring the temperature of its water bath, assuming thermal equilibrium. This is the initial temperature of the calorimeter lining and water.

8. Place the object quickly into the calorimeter and place the lid on top. Insert the temperature probe into the lid so that it is measuring the water temperature. Wait for thermal equilibrium to record the final temperature. This is the final temperature of the calorimeter lining, the water and the object.

9. Calculate the specific heat of the object using the formula under the section “Review of Theory”.

Specific Latent Heat of Condensation of Water

Syllabus reference	3.2
Assessment Criteria	Planning B Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	
Aim	Determine the specific heat of condensation water

Research question

In planning B you are going to make (among other things) a hypothesis corresponding to the following research question: Is it possible to determine the specific latent heat of condensation of water to within 5% of the accepted value in literature using only equipment found in a typical high school?

Equipment and Measurement procedure

This is your problem, not mine ☺.

Follow-up question after lab

Explain, from a microscopical point of view, how the specific heat of condensation of water will relate to the specific heat of vaporisation of water.

Specific Latent Heat of Fusion of Water

Syllabus reference	3.2
Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	One week after delivered out
Aim	Determine the specific latent heat of fusion of water.

Equipment

CBL2
Temperature Probe
Calorimeter
Ice Cubes
Water
Paper towels

Review of Theory

To measure the specific latent heat of fusion of water substance, we need to use a method that minimizes the heat loss to the surroundings. We start with a calorimeter with water that has a temperature about 5ºC above the room temperature. Then we add an ice cube at 0ºC and stir gently until the cube is totally melted. This procedure is repeated until the temperature of the water is 5ºC below the room temperature.

With this procedure the heat lost to the surroundings, when the temperature of the calorimeter and its contents was above room temperature, must be approximately equal to the heat gained from the surroundings when it was below the room temperature.

According to the law of conservation of energy the heat lost by the water and calorimeter must be equal to the heat needed to melt the ice into water at 0ºC and raise the temperature of this water to T_f:

$$m_w c_w \Delta T_w + C\Delta T_c = m_{\text{ice}} l_{\text{ice}} + m_{\text{ice}} c_w \Delta T_{\text{ice}}$$

or

$$l_{\text{ice}} = \frac{m_w c_w \Delta T_w + C\Delta T_c - m_{\text{ice}} c_w \Delta T_{\text{ice}}}{m_{\text{ice}}}$$

Measurement procedure

9. Record the room temperature T_f.

10. Find five ice cubes, put them in a beaker and add water to cover the ice. After five minutes we can assume that the temperature of the ice and the water is at 0ºC.

11. Determine and record the mass m_c of the calorimeter.

12. Pour 200mL water at a temperature 4-8ºC above room temperature into the calorimeter. Put a thermometer into the water. Wait one minute until the calorimeter has reached thermal equilibrium with the water. Measure and record the initial temperature T_i of the water and the calorimeter.

13. Determine and record the mass m_w of the water by weighing the calorimeter with water on the digital scales.

14. Add an ice cube initially dried on a paper towel to the water and stir until it is melted. Repeat the process until the water temperature is the same amount below room temperature as the initial temperature was above. Record the final temperature T_f.

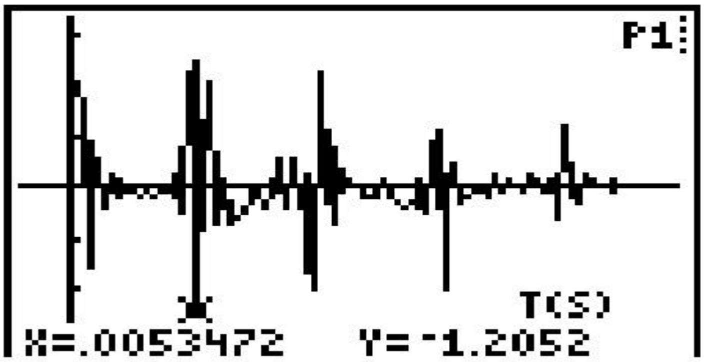
15. Determine and record the mass m_{ice} of the ice added by weighing the calorimeter on the digital scales.

16. Use the data under steps 1-7 to determine the specific latent heat of fusion of water l_{ice}.

Speed of Sound by Reflection

Syllabus reference	4
Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	One week after delivered out
Aim	The aim of this investigation is to determine the speed of sound waves.

Equipment



CBL
Microphone
Air column of minimum 1 m length
Calculator

Measurement procedure

Set up the microphone in trigger mode.

Hold the microphone close to the end of the air column and make a snap with your fingers. If you get a series of distict wave tops, use trace to determine the time difference between them. If you are not satisfied the microphone may be not close enough.

Data analysis

Use the values for time and length in the previous paragraph to determine the speed of sound. How far has the sound wave travelled ?

Speed of Sound in CO_2

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

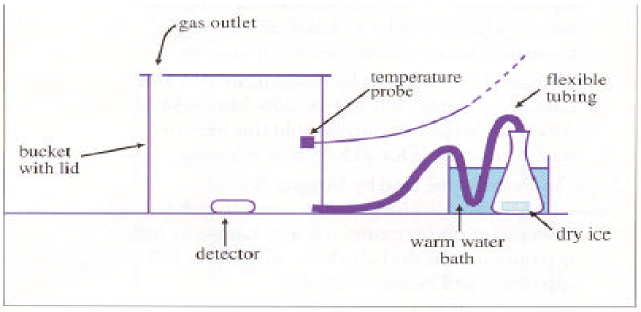
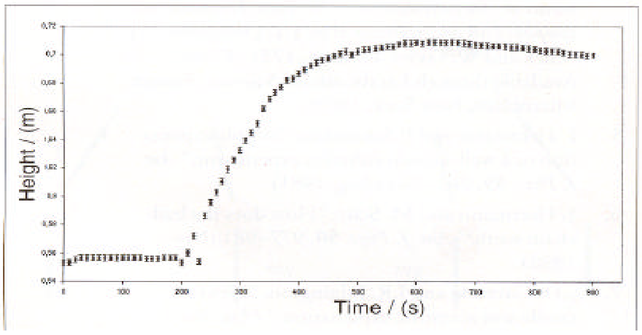


Fig. 1. Experimental setup.



Equipment

Bucket

Temperature probe
Motion detector
Dry ice

Procedure

Put the motion detector inside a bucket with a reflecting plate on the top. There should be a small hole on this plate. Measure now the height to the plate every tenth second for 15 minutes. After about 200 seconds lead carbon dioxide into the bucket.

Analysis

Explain how the height in air and the maximum height in carbon dioxide will give you the speed of sound in carbon dioxide if you know the the speed of sound in air assumed by your motion detector (see your manual).

Reference

Inge H. A. Pettersen, *Speed of Sound in Gases Using an Ultrasonic Motion Detector*, The Physics Teacher, Vol. 40, May 2002, pp. 284 – 286.

Static and Kinetic Friction

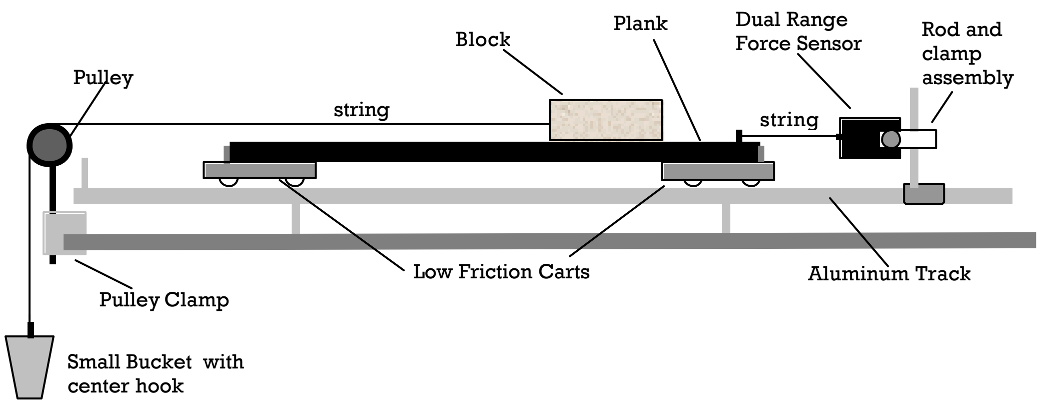
Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Low friction carts, aluminum track, wood plank, wood block, other blocks, metal and plastic sheets, triple-beam balance, clamps, rods, string, small bucket, large bucket, fine dry sand, beaker, pulley, weights, force sensor

Set-up

Set up the apparatus as shown in the diagram below:



Friction Force Experiment Apparatus

In the situation shown in the diagram, the strings are both horizontal, as are the track and plank. The low friction carts support the plank. The weight of the bucket and its contents creates a tension in the long string, which pulls on the block. The block exerts a friction force

on the plank that tries to pull the plank toward the pulley; the short string that attaches the plank to the force sensor prevents the plank from moving.

Since the plank cannot move, the sum of the forces on it must be zero. Because of the low-friction carts, the only significant horizontal forces on the plank are the friction force from the block and the tension in the short string. Since these must add up to zero, their magnitudes must be equal. Thus the force sensor records the magnitude of the friction force that the block exerts on the plank (and by Newton's third law, the magnitude of the friction force that the plank exerts on the block.)

Procedure

- Use the triple-beam balance to determine the mass of the block.

- Set up the apparatus as shown in the diagram, making sure the track is level. The plank should be fitted between the long machine screws that are to be screwed into the tops of the carts, one screw on each cart.

- Place the large bucket on the floor so that the small bucket will go into it as it descends.

- Start collecting and as soon as data collection begins, begin pouring the sand slowly and steadily into the small bucket; cease pouring when the bucket starts to descend.

Analysis

Observe the graph of force versus time. It should show a distinct difference between the static and kinetic friction forces (the static friction force should increase with time until the block starts to move; the kinetic friction section probably will show some oscillations due to the elasticity of the force sensor; these will be averaged out below.) If not, try again; the proper pouring rate for the sand may take some practice. If you have a good graph, magnify the significant part and then go on to the next step.

On the graph; click and drag across the kinetic friction portion; then click the Analysis button to get he mean value of the kinetic friction force; move the statistics box to so that it does not obscure any of the graph. Click and drag across no more than five points at the peak of the static friction portion of the graph; click the statistics button to get the mean value of the maximum force of static friction; make sure this box does not obscure any part of the graph; Record the mean values of ;the forces in the data table and then save the graph to the floppy disk.

If time permits, repeat the measurement procedure until you have five good graphs.

Calculate and record the average (of the five trials) value of the maximum force of static friction.

Calculate and record the average (of the five trials) value of the kinetic friction force.

Use the average force values to determine the coefficients of static and kinetic friction for the block on the plank; keep only one significant figure for each coefficient.

Select one of the saved graphs and print it as an example to include with your calculations.

Extension

1. Place a 500 gram weight on top of the block and repeat the experiment. You may have to hang an extra weight to the small bucket in order for the sand to cause the block to break loose; a loop of strong cord on the bucket will allow this weight to hang below.

2. Turn the block onto its edge and repeat the experiment without the added weight.

3. Do the experiment using one of the other blocks (metal, plastic, etc) and/or one of the metal sheets which you can clamp to the top of the plank.

Analysis of extension

Do the graphs support the ideas embodied in the equations $f_s \leq m_s N$ and $f_k = m_k N$? Discuss.

If you did extensions 1 and 2, do the results support the idea that the coefficients of friction are independent of the load and of the area of contact? Discuss.

If you did extension 3 do the results support the idea that coefficients of friction depend on the materials being used? Discuss.

Acknowledgement

Thanks to Leo Takahashi who has supplied the file “Static and Kinetic Friction Experiment.rtf” corresponding to his article “A Friction Experiment” in The Physics Teacher, Vol. 40, Sep. 2002, pp. 374 – 375. This experiment is with minor modifications his worksheet.

An alternative version using a motion detector in a hanging mass-pulley system can be found in R. Morrow, A. Grant, D. P. Jackson *A Strange Behavior of Friction*, The Physics Teacher, Vol. 37, Oct. 1999, pp. 412 - 415.

Data Sheet

Mass of block (and load):____

Trial	Maximum force of static friction	Force of kinetic friction
1		
2		
3		
4		
5		
average value		

Coefficient of Static Friction:____

Coefficient of Kinetic Friction:_______________________________________

Mass of block (and load)____

Trial	Maximum force of static friction	Force of kinetic friction
1		
2		
3		
4		
5		
average value		

Coefficient of Static Friction:___________________________________

Coefficient of Kinetic Friction:___________________________________

Student Motion

Assessment Criteria	Data Collection Data Processing and Presentation Conclusion and Evaluation
Date delivered out	
Date for handing in	
Aim	Investigate motion of students

Equipment

Motion sensor (at least 20 points/sec.)
Students

Summary of lab

In this lab you are going to graph position vs time of fellow students walking with constant velocity. Form groups of 2 – 3 persons in the school yard and make measurements of motion of one student with the sensor as indicated below.

Data collection

Phase 1	First one student is moving steadily and slowly towards the sensor. Then do the same measurement under the same conditions, except that now the motion is faster (but still steady).
Phase 2	Do the same as in phase 1, but moving now away from the sensor.
Phase 3	Each student in the group is supposed to make a position/time graph of a motion with constant velocity with a readable initial position within the range of the sensor and with units along the axes so that the velocity can be computed. Exchange the graphs and each student makes a try to fit the graph.

Data analysis

Phase 1 and Phase 2	Make a graph of position vs. time for each movement. Make a graph of velocity vs. time for each movement.
Phase 3	Make a graph of the result of trying to fit the initial graph. Comment on the degree of fit with respect to position and with respect to velocity.

Questions

How do you find velocity at a particular instance of time from a position/time graph?

How do you find average velocity during a particular interval of time from a position/time graph?

Sweet Physics

Syllabus reference	
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	One week after delivered out
Aim	Review statistical concepts

Equipment

A full bag of similar candies (say 80)
Spreadsheet

Part 1 – Brainstorming

In small groups the students are brainstorming before writing down the measures of central tendency and measures of variability they know from statistics. After 5 – 10 minutes the teacher summarize the results.

Part 2 – Statistical analysis

The sweets are divided equally between the groups and each group measure the mass of each candy. The results are written on the blackboard. Each group should then calculate the statistical quantities in part 1 both for the data collected by their group as well for the total data collected by the whole class.

Part 3 – Histogram

Choose a reasonable histogram bin and use a spreadsheet to graph number of candies (of the whole class) versus mass. Each participant should get a print-out.

Questions

How do the results for your group compare with the results for the whole class? Did you expect this?

How do the graph compare with the quantities you calculated in part 2?

Reference

Chuck Stone, “”Sweetening” Technical Physics with Hershey’s Kisses”, The Physics Teacher, Vol. 41, Apr. 2003, pp. 234 – 237.

Terminal Velocity of Balls and Balloons

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

A spherical balloon and a ball of similar cross section area
Motion sensor
Water

Part I – Procedure and analysis for the balloon

In order to avoid air currents during the following experiments, close windows and doors and restrict movement of the members of the group.

Measure the mass of the balloon and let the balloon fall towards a motion detector placed on the floor. Use a data analysis program like Graphical Analysis to make a plot of velocity versus time. Use this plot to determine the terminal velocity.

Fill the balloon with a small amount of water and measure again the mass. The new balloon should have the same cross section area as the previous balloon. Determine once again the terminal velocity. Continue with increasing the mass until you have ten masses and ten terminal velocities.

If the friction of air is assumed to increase as a power of the speed, $F_{air} = kv^n$, the terminal velocity v_T is related to the mass m and the acceleration of gravity g by the formula $\log m = n \log v_T + \log \frac{k}{g}$ (why?). Use this formula together with the ten data pairs to find graphically best fit values of n and k. In particular find also the best value for k if you demand n to be 2.

Part II – Procedure and analysis for the ball

Measure the mass m_{ball} of the ball and determine displacement vs time when the ball is falling. For the value of k found in part I when n=2, make a plot in a data analysis program of $a + \frac{k}{m_{ball}} \cdot v^2$ where a is the acceleration. What form should the graph have theoretically if k and n are correct?

Reference

The idea for this lab was obtained from the article P. Gluck, *Air resistance on Falling Balls and Balloons*, The Physics Teacher, Vol. 41, Mar. 2003, pp. 178 - 180.

Terminal Velocity of Balloons Revisited

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Spherical balloons of various diameter
Motion sensor

Introduction

In the previous lab you saw that the air friction could be considered to be approximately proportional to the square of the speed, $F_{air} = kv^2$. We will in this lab assume that this is the true relation.

In stead of filling balloons with water, we will now use spherical balloons with various diameters and then determine how the constant k depends on the cross section area: Should the constant k increase or decrease if the area is increasing (hint: consider the work that has to be done in order to push away the air in front of the balloon)?

What you are expected to do

1. Make a simple hypothesis on how the constant k will depend on the area.

2. Plan an experiment on how this relation can be tested experimentally

3. Do this experiment and evaluate your results

The Coke Bottle - a Helmholtz Resonator?

Syllabus reference	
Assessment Criteria	Data Processing and Presentation
Date delivered out	
Date for handing in	One week after delivered out
Aim	To determine the resonances of a bottle of Coke and consider if it can be modelled as a Helmholtz resonator.

Equipment

Water
Coke bottle
CBL2 w/microphone probe

Measurement procedure

1. Use the CBL to measure the fundamental resonance frequencies of a bottle of coke as a function of the distance d from the water level to the top.

2. Use Graphical Analysis to find the best model of the resonance frequency, using maximum two free parameters.

Question

According to M.P. Silverman and E. R. Worthy in The Physics Teacher, Vol. **36** (1998) pp. 70 - 74, a good model for the fundamental frequency is $f = \frac{A}{\sqrt{d - B}}$. How does their result compete with your model (compare mean square error)?

What values would you expect of the higher order frequencies in units of the fundamental frequency for a given water level?

The Impulse Law on an Air Track

Syllabus reference	
Assessment Criteria	Data Processing and Presentation, Evaluation
Date delivered out	
Date for handing in	
Aim	The aim of this investigation is to investigate the validity of the impulse law

Equipment

Air track with two wagon and loads
Two magnets
Ultra Sonic Motion Detector and Student Force Sensor

Procedure

Check first that the air track is horizontal by releasing a wagon from rest. If the wagon accelerates, adjust the air track and try again.

Put both wagons on the air track. Fasten one magnet on each wagon in such a way that that if the wagons come close to each other, they will repel. Put one CBL on each end of the air track. Measure now the distance vs time of the two wagons after they have been put in motion. If the wagons do not reflect properly the sound waves, put a small and stiff sheet of paper on each wagon.

Use Graphical Analysis to make a velocity vs time graph for each wagon. Calculate the total linear momentum before and after the collision. Compare.

Use the velocity vs time graph to make an acceleration vs time graph for each wagon. After measuring the masses of the wagons, make also a graph of magnetic force vs time for each wagon. Compute now in Graphical Analysis the area under the force vs time graph for each wagon and compare the results.

Thermodynamical Activities

Aim	Determine the relative accuracy of two thermometers.
Group size	Three
Equipment needed	Temperatue probe, glass thermometer, two containers for ice water and hot tap water, stop watch, cleaning paper

Part 1 - Relative accuracy of thermometers

Pre Questions

1. Suppose you want to measure room temperature with a thermometer that has been in ice water. Which do you predict would cause more time delay – measuring room temperature water or room temperature air? Explain the reason for your prediction.

Procedure

1. Use the CBL temperature probe to verify your prediction using a time graph. NB! Make sure that the temperature probes after leaving the ice water is made dry by removing remaining water drops with some cleaning paper.

2. Sketch the two time graphs.

Post Questions

1. On the bases of these measurements, what should you watch out for in making temperature measurements?

2. The temperature difference between room temperature and ice water is about 20°C. What do you think will happen to the measured time delays if the temperature of the sensor is only two degrees below room temperature?

Part 2 - Defining a Temperature Scale Operationally

Aim	The aim of this activity is to define a temperature scale of your own. In addition the direction of thermal energy transfer is determined between the thermometer and the objects.
Group size	Two
Equipment needed	Glass thermometer, ruler, transparent tape, marking pen, various objects of interest (salt, tap water, water ice, dry ice,….)

Procedure

1. Seal the scale of the glass thermometer with transparent tape.
2. Choose two objects whose temperature you suspect are different and seem convenient to measure. Assign different values (fixed points) to the temperatures of these two objects and use your marking pen to mark these two points on the tape.
3. Use a ruler to make a rough temperature scale.
4. On your scale, determine the room temperature, ice water temperature, and your body temperature (arm pit). Also read of the Celsius scale.

	Your temperature scale	Degree Celsius
Room		
Ice water		
Arm pit		

Post Questions

1. Are the fixed points reliable, i. e. are they truly fixed?
2. If given more time and better apparatus, could you have chosen more reliable ones? Explain and give an example of a more reliable fixed point.
3. When the thermometer is in thermal contact with the three objects, argue in each case the direction of heat transfer.

Syllabus questions

1. State the relation between the Kelvin and the Celsius scales of temperature in word.
2. How would you in general terms explain how a temperature scale is defined?

Part 3 - Thermal equilibrium

Aim	The aim is to use the concept of thermal equilibrium to explain some effects.
Group size	Two
Equipment needed	Glass thermometer, clay or cleaning paper, Styrofoam with hole, meal with hole

Procedure

1. Feel the clay/cleaning paper, the Styrofoam and the metal. Predict which object actually has the highest and lowest temperature.

2. Use the thermometer to find the actually values

Metal	(°C)
Clay or cleaning paper	(°C)
Styrofoam	(°C)

Post Questions

1. Did your observation jibe with your prediction? Is your sense of touch an accurate predictor of relative temperatures?

2 Should the temperatures near the surface of three different materials sitting around in the same room be the same or different?

3. Why do some objects feel colder than others?

Part 4 - Heat transfer

Aim	The aim of this activity is to describe qualitatively the three main processes of heat transfer.
Group size	Two
Equipment needed	A long and a short piece of iron nail, a candle, your hand

Procedure

1. Light the candle

2. Move your flat hand towards the flame from above. Notice how near you may put your hand before it hurts.

3. Move your flat hand towards the flame from the side. Notice again how near you may put your hand before it hurts. Compare with the distance under part 2

4. Put one end of the metal pieces simultaneous in the flame. Notice which of these pieces you have to drop first.

Post Questions

1. Identify the procedure steps that correspond to conduction, radiation and convection

2. Based on the results in 2 and 3, it is possible to state the relative significance of two processes of heat transfer. Explain.

Part 5 - Heat and internal energy

Aim	Review the theoretical ideas behind the concepts of heat and internal energy.
Group size	Two or three
Equipment needed	A sheet of paper, pencil and a good understanding.

Procedure

Based on what you have done so far in thermal physics by experiments and theory sessions, answer these questions:

1. What is the difference between a macroscopic and a microscopic view of matter? Use examples!

2. Give the microscopic meaning of temperature, i. e. what is it a measure of?

3. Give also the microscopic meaning of internal energy.

4. How can we understand the concept of heat microscopically?

5. Define the concepts of temperature, internal energy, and heat macroscopically.

Using a Graphing Calculator to Study Waves

Syllabus reference	
Assessment Criteria	Data Analysis
Date delivered out	
Date for handing in	
Aim	

Equipment

graphical calculator

Important note

The following settings apply to the TI-81 calculator:

Mode Settings	Norm; Float 2; Rad; Function; Connected; Sequence;Grid Off; Rect.
Range Settings	Xmin = 0 Xmax = 2 Xscl = 0 Ymin = -3 Ymax = +3 Yscl = 0 Xres = 1

It should be easy to modify this file in order to make it consistent with the calculator type of your school.

Part I: Graphing Basic Waves

1. Enter Y1 = sin[2(pi)x] and graph it
   (a) Trace the graph to determine the wavelength and the amplitude of the wave.

2. Enter Y1 = 2sin[2(pi)x] and graph it
   (a) How does this wave differ from the previous wave? Be specific! Be numerical!

3. Enter Y1 = sin[4(pi)x] and graph it
   (a) What is the wavelength and the amplitude?

4. Write the equation of a wave that would have the same wavelength as in the previous part; but which would have an amplitude of 3. Test your prediction by entering your equation on the calculator and graphing it. Does it work?

5. Write the equation of a wave that has an amplitude of 2 and a wavelength of 2. Test your prediction. Does it work?

6. Write the equation of a wave that has an amplitude of 1 and a wavelength of 0.25. Test your prediction. Does it work?

7. What is the general rule for determining the amplitude from the equation for a wave?

8. What is the general rule for determing the wavelength from the equation for a wave?

Part II: Traveling Waves

1. Graph the following. Be careful with the parentheses as you type the equations in and watch the screen carefully as the calculator performs the graphing

Y1 = sin[2(pi)x]
Y2 = sin[2(pi)(x - 0.25)]
Y3 = sin[2(pi)(x - 0.50)]
Y4 = sin[(2pi)(x - 0.75))

As the calculator graphs each equation sequentially; would you say the waves are moving to the right or moving to the left. By how much does each wavecrest move from one wave to the next?

2. Graph the following. Notice that all you are doing is changing the minus signs to plus signs. Watch the screen carefully as the calculator performs the graphing

Y1 = sin[2(pi)x]
Y2 = sin[2(pi)(x + 0.25)]
Y3 = sin[2(pi)(x + 0.50)]
Y4 = sin[(2pi)(x + 0.75))

As the calculator graphs each equation sequentially; would you say the waves are moving to the right or moving to the left? By how much does each wavecrest move from one wave to the next?

Part III: Combining Moving Waves

1. Enter Y1 = sin[2(pi)x]; Y2 = (1.1)sin[2(pi)x]; Y3 = Y1 + Y2. The first two waves are being drawn with slightly different amplitudes so you can distinguish between them on the screen. Ideally, they should have the same amplitudes.
   (a) Note the location and height of all crests and troughs
   (b) Use a full sheet of paper to draw a carefull sketch of all three lines

2. Enter Y1 = sin[2(pi)(x - 0.25)]; Y2 = sin[2(pi)(x + 0.25)); Y3 = Y1 + Y2. Be careful with the parentheses when entering the equations.

(a) Note the location and the height of all crests and troughs.

(b) Use a full sheet of paper to draw a sketch of all three lines.

3. Repeat the previous part using the equations: Y1 = sin[2(pi)(x -0.5)]; Y2 = sin[2(pi)(x + 0.5)]; Y3 = Y1 + Y2.

4. Repeat the previous part using the equations: Y1 = sin[2(pi)(x -0.75)]; Y2 = sin[2(pi)(x + 0.75)]; Y3 = Y1 + Y2.

5. Repeat the previous part using the equations: Y1 = sin[2(pi)(x - 1.0)]; Y2 = sin[2(pi)(x + 1.0]; Y3 = Y1 + Y2.

6. Explain how this part of the experiment illustrates what happens with standing waves.

Part IV: Combining waves with distinctly different wavelengths/amplitudes

1. On the (Y= screen) enter

Y1 = 2 sin[2(pi)x]
Y2 = 0.5sin[10(pi)x]
Y3 = Y1 + Y1

2. First just graph Y1 and Y2. If you dont know how to turn functions on and off for graphing, please ask for assistance. How many wavelengths of Y2 fit into one wavelength of Y1?

3. Then turn off Y1 and Y2 and turn on Y3. Discuss how the graph of Y3 shows both the properties of Y1 and of Y2.

4. Repeat all the previous steps of this part leaving everything the same with the exception of changing the Y2 equation to:

Y2 = 0.5 sin[20(pi)x]

5. Discuss how this part of the experiment shows how a string can simultaneously be vibrating in its fundamental frequency and in some of its overtones and how the different possible mixtures of overtones can contribute to the timbre or the quality of the sound being produced.

PART V: Combining waves with the same amplitude and close frequencies

1. On the y= screen set:

Y1 = sin[15(pi)x]
Y2 = sin[20(pi)x]
Y3 = Y1 + Y2

2. First just graph Y1 and Y2. Comment on how the graphs.

3. Then just graph Y3. Sketch this graph on your lab report and describe what it looks like in words

4. Change Y1 and Y2 to:
Y1 = sin[17(pi)x]
Y2 = sin[20(pi)x] and leave
Y3 = Y1 + Y2

5. Just graph Y3. Sketch this graph on your lab report and describe how it differs from the graph of Y3 in # 3.

6. Set Y1 = sin[19(pi)x] and leave Y2 and Y3 as
Y2 = sin[20(pi)x] and
Y3 = Y1 and Y2

7. Just graph Y3 and sketch the graph on your lab report. Comment on how it differs from the other two graphs of Y3 in this part.

8. Comment on how this part of the exercise illustrates how beats are formed and use your results to discuss how the nature of the beats formed depends on the frequency differences between the two individual of waves.

PART VI: Some special graphs

1. Set Y1 = sin[x] + 0.5sin[2x] + 0.333sin[3x] + 0.25sin[4x] + 0.2sin[5x]
Y2 = sin[x] + 0.333sin[2x] + 0.2sin[5x] + 1/7sin[7x] + 1/9sin[9x]
Y3 = sin[x] + 1/9sin[3x] + 1/25sin[5x] + 1/49sin[7x] + 1/81sin[9x]

2. Just graph Y1 and sketch the graph on your lab report. Do the same for Y2 and Y3.

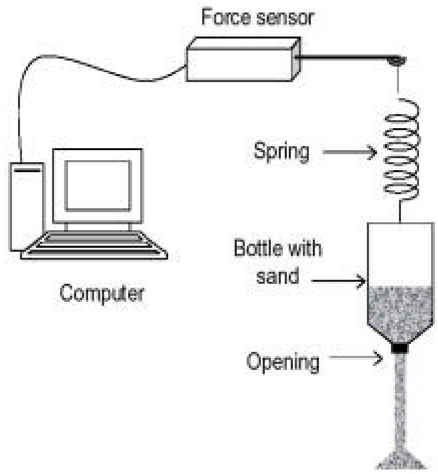
3. The graphs above have been called the square, the triangle, and the sawtooth waves. Can you identify the name of each graph Y1, Y2, and Y3?

Acknowledgements

This lab is mainly based on a lab given by Edwin Schweber on the mailing list physhare in a message with date Sat, 4 Mar 1995 05:48:40 –0800 and with subject “Studying Waves With Graphics Calculatore”. It has be modified due to a comment by Gary Garber on the same list with date Sat, 4 Mar 1995 19:48:08 PST and with subject “Re: Studying Waves With Graphics Calculatore”.

Variable Mass Oscillator

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Get experience in data fitting



Equipment

Force sensor
Springs of various spring constants
Plastic bottle without bottom
Sand

Procedure

Set up the equipment as shown in the picture above. With the opening of the inverted bottle closed, fill sand into the bottle through the open bottom.

Pull the bottle out of equilibrium, remove the cap, and release the bottle. When the bottle is set in motion, the force sensor should start collecting data. The data collected should now be analyzed according to the section Analysis below.

Repeat the measurement for strings with other string constants.

Analysis

Use Graphical Analysis to model each set of data of force vs time as a decaying sine curve, i. e., $F = B + A\exp(-\gamma t)\sin(\omega t + \phi)$.

After collecting several angular velocities, make a plot of the square of angular velocity versus spring constant.

Questions

- What does the constant B represent? Do a simple experiment to verify your answer.
- Guess at least one factor the constant γ depend on and suggest an experimental procedure of how one could test your suggestion.

Acknowledgement

Salvador Gil sent me the file "Variable Mass Oscillator.pdf" based on his articles "Flow of sand and a variable mass Atwood machine" and "Variable mass oscillator" in American Journal of Physics July 2003 (for those who teach in Spanish, his web site http://www.fisicarecreativa.com about physics teaching is worth a visit). This experiment is based on the ideas in this worksheet.

Vector Addition

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Find resultant vectors by five different methods

Some student might not have knowledge about the laws of cosines and the laws of sines. They should then drop the analytical method.

Equipment

3 hangers and pulleys
slotted mass set,
string,
ruler and protractor

Experimental method

Set up the vector calculator with three pulleys and strings. Screw the center post of the vector calculator up so that the ring on the three strings is around the center post.

Hang the following masses on two of the pulleys and clamp the pulleys at the given angles:

F_1 = 50.00 g at 0.0° F_2 = 50.00 g at 150.0°

Using trial and error, find the correct mass and angle on the third pulley in order to achieve equilibrium. This is the equilibrant vector for the two vectors. To check for equilibrium, screw the center post down so it will not contact the ring. Pull the ring slightly and let it go. Be sure that the ring always returns to the center. If not, adjust the angle and/or mass slightly. The resultant vector is equal in magnitude to the equilibrant, and opposite in direction.

Component method

Draw and calculate the two components of each vector. Show the calculations to add the components back together to get the components of the resultant. Then calculate its magnitude and direction. Show all work including all three diagrams.

Analytical method

Draw the vectors head-to-tail. Then use the law of sines and law of cosines to calculate the magnitude and direction of the resultant vector for the two given vectors. Show all work including one diagram.

Graphical method

Below the analytical method, draw a scaled diagram of the two vectors using a ruler and protractor. Write your scale in the space provided. Graphically add the vectors head-to-tail and draw the resultant. Measure the magnitude and direction of the resultant.

TI-89 calculator method

Your TI-89 calculator can add vectors quite easily. You use what is called Polar form, which you may be familiar with from your math class. You enter the vectors to be added in this form:

`[magn,∠angle] + [magn,∠angle]▶ Polar` [ENTER]

You will find the `Polar ▶` either in the `CATALOG` or through this sequence:

[2ND] [MATH] 4 [ALPHA] L 4

The polar conversion will give the resultant in magnitude and direction. If you leave it off, you will get the components of the resultant.

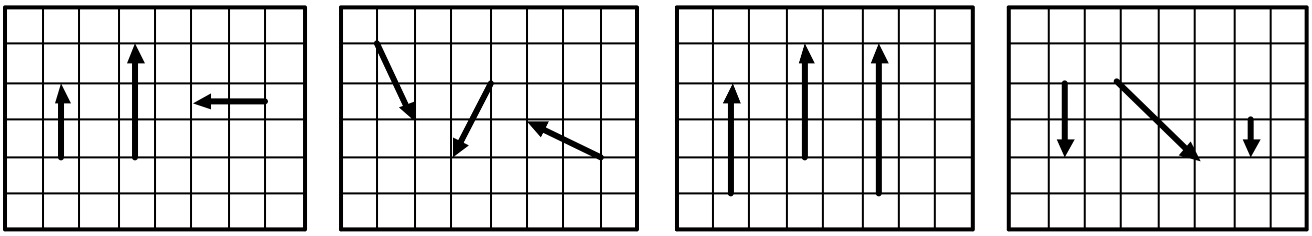
Acknowledgement

This is a modified experiment based on a worksheet “Exp vectors2001.rtf” designed by Jeff McManus who offered it in a message called "Re: Force Tables" to the mailing list physhare Mon, 7 Oct 2002.

Appendix – Homework worksheet

1. In the four boxes below are collections of vectors on top of equally spaced grid lines. Choose the answer from the list below that most correctly describes the comparative **magnitudes** of the vectors within each box.

Box A **Box B** **Box C** **Box D**

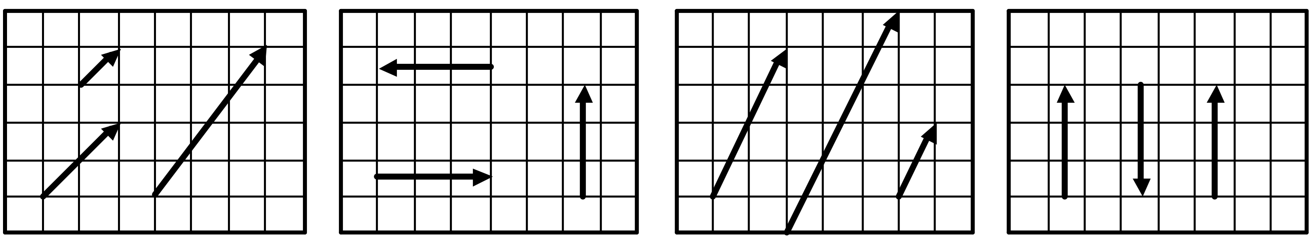


Possible Answers. Select the best one.

A. Box **A** has all vectors with the same magnitude
B. Box **B** has all vectors with the same magnitude
C. Box **C** has all vectors with the same magnitude
D. Box **D** has all vectors with the same magnitude
E. None of the above boxes have all vectors with the same magnitude

2. In the four boxes below are collections of vectors on top of equally spaced grid lines. Choose the answer from the list below that most correctly describes the comparative **directions** of the vectors within each box.

Box A **Box B** **Box C** **Box D**

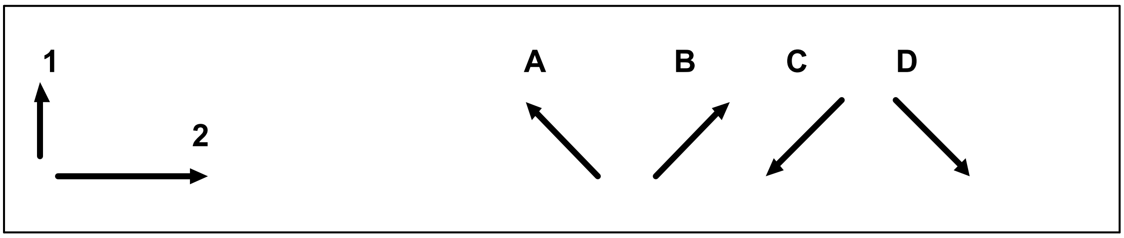


Possible Answers. Select the best one.

A. Box **A** has all vectors with the same direction
B. Box **B** has all vectors with the same direction
C. Box **C** has all vectors with the same direction
D. Box **D** has all vectors with the same direction

E. Both boxes **A** and **C** have vectors that all have the same direction
F. Both boxes **A** and **D** have vectors that all have the same direction
G. Both boxes **C** and **D** have vectors that all have the same direction
H. The boxes, **A**, **C**, and **D** have vectors that all have the same direction
I. None of the above boxes have vectors with the same direction

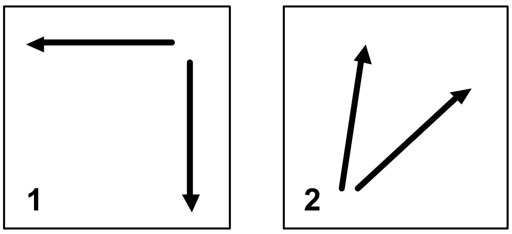
3. Below are shown two vectors $\vec{\mathbf{1}}$ and $\vec{\mathbf{2}}$. Consider $\vec{\mathbf{R}}$, the vector sum (the "resultant") of $\vec{\mathbf{1}}$ and $\vec{\mathbf{2}}$, where $\vec{\mathbf{R}} = \vec{\mathbf{1}} + \vec{\mathbf{2}}$. Which of the other four vectors shown ($\vec{\mathbf{A}}, \vec{\mathbf{B}}, \vec{\mathbf{C}}, \vec{\mathbf{D}}$) if any has most nearly the ***same direction*** as $\vec{\mathbf{R}}$?



Possible answers. Select the best one.

A. Vector $\vec{\mathbf{A}}$ has a direction most nearly the same as the resultant $\vec{\mathbf{R}}$
B. Vector $\vec{\mathbf{B}}$ has a direction most nearly the same as the resultant $\vec{\mathbf{R}}$
C. Vector $\vec{\mathbf{C}}$ has a direction most nearly the same as the resultant $\vec{\mathbf{R}}$
D. Vector $\vec{\mathbf{D}}$ has a direction most nearly the same as the resultant $\vec{\mathbf{R}}$
E. None of the above. None of the vectors shown has a direction that is similar to that of the resultant $\vec{\mathbf{R}}$.

4. In the boxes below are two pairs of vectors, pair **1** and pair **2**. (All arrows have the same length.) Consider the magnitude of the ***resultant*** $\vec{\mathbf{R}}$ (the vector sum) of each pair of vectors. Is the magnitude of the resultant of pair **1,** $|\vec{\mathbf{R}}_1|$, *smaller than*, *equal to*, or *larger*



than the ***magnitude*** of the resultant of pair **2,** $|\vec{\mathbf{R}}_2|$?

Possible Answers. Select the best one.

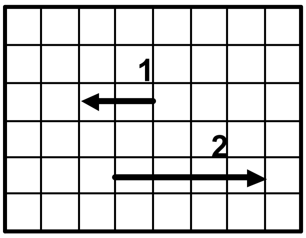
A. Magnitude of the resultant of pair **1** is smaller than pair **2,** i.e., $\left|\vec{\mathbf{R}}_1\right| < \left|\vec{\mathbf{R}}_2\right|$

B. Magnitude of the resultant of pair **1** is equal to pair **2,** i.e., $\left|\vec{\mathbf{R}}_1\right| = \left|\vec{\mathbf{R}}_2\right|$

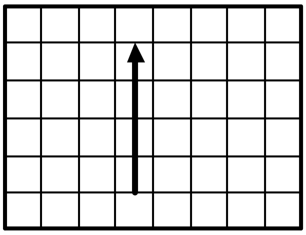
C. Magnitude of the resultant of pair **1** is greater than pair **2,** i.e., $\left|\vec{\mathbf{R}}_1\right| > \left|\vec{\mathbf{R}}_2\right|$

D. None of the above. The magnitudes of the resultants cannot be compared.

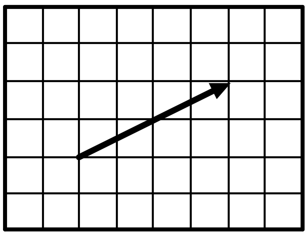
5. Consider the two vectors $\vec{\mathbf{1}}$ and $\vec{\mathbf{2}}$ in the box with the grid below. Choose the answer that gives the correct resultant $\vec{\mathbf{R}} = \vec{\mathbf{1}} + \vec{\mathbf{2}}$ of vector addition of the two component vectors.



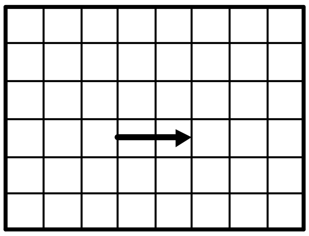
Box A



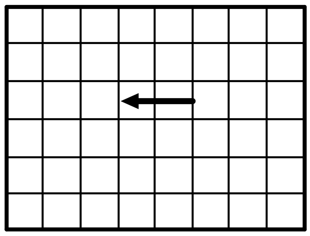
Box B



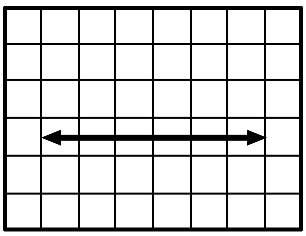
Box C



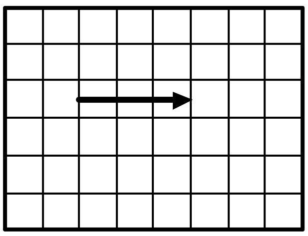
Box D



Box E



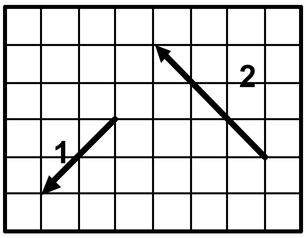
Box F



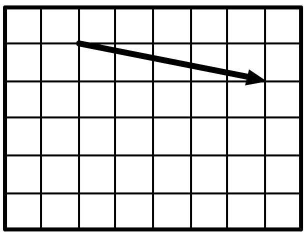
Possible answers. Select the best one.

A. Box **A** has the vector that is the correct resultant $\vec{\mathbf{R}}$
B. Box **B** has the vector that is the correct resultant $\vec{\mathbf{R}}$
C. Box **C** has the vector that is the correct resultant $\vec{\mathbf{R}}$
D. Box **D** has the vector that is the correct resultant $\vec{\mathbf{R}}$
E. Box **E** has the vector that is the correct resultant $\vec{\mathbf{R}}$
F. Box **F** has the vector that is the correct resultant $\vec{\mathbf{R}}$
G. None of the above has the correct resultant $\vec{\mathbf{R}}$

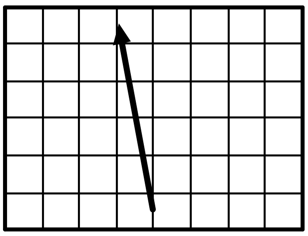
6. In the figure below there are two vectors $\vec{\mathbf{1}}$ and $\vec{\mathbf{2}}$. Choose a vector from the boxes below that most closely resembles the sum or vector addition $\vec{\mathbf{R}}$ of the two, (i.e., $\vec{\mathbf{R}} = \vec{\mathbf{1}} + \vec{\mathbf{2}}$).



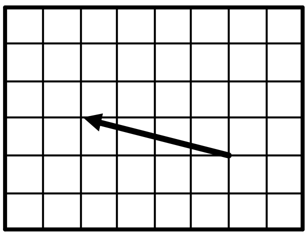
Box A



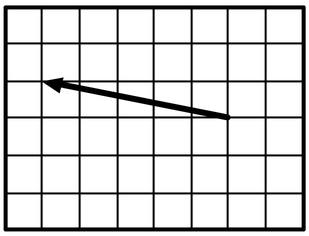
Box B



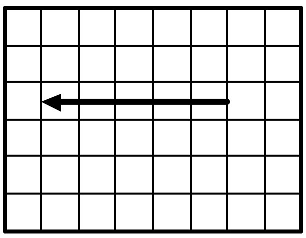
Box C



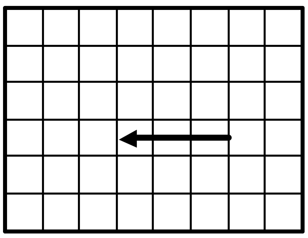
Box D



Box E



Box F



Possible answers. Select the best one.

A. Box **A** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$
B. Box **B** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$

C. Box **C** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$

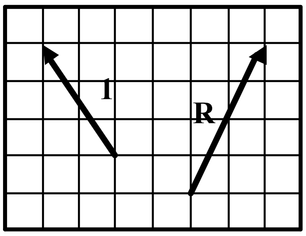
D. Box **D** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$

E. Box **E** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$

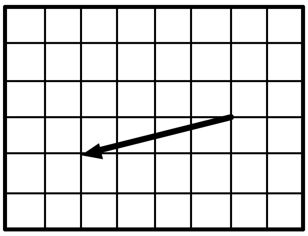
F. Box **F** has a vector that most closely resembles the correct resultant $\vec{\mathbf{R}}$

G. None of the above. None of the vectors closely resembles the correct resultant $\vec{\mathbf{R}}$

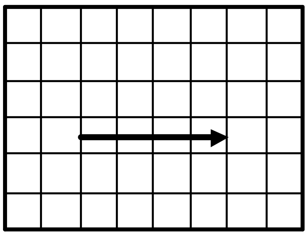
7. In the figure below, a vector $\vec{\mathbf{R}}$ is shown that is the ***net resultant*** of two other vectors $\vec{\mathbf{1}}$ and $\vec{\mathbf{2}}$ (i.e. $\vec{\mathbf{R}} = \vec{\mathbf{1}} + \vec{\mathbf{2}}$). Vector $\vec{\mathbf{1}}$ is given. Find the vector $\vec{\mathbf{2}}$ that when added to $\vec{\mathbf{1}}$ produces $\vec{\mathbf{R}}$. **DO NOT** try to combine or add $\vec{\mathbf{1}}$ and $\vec{\mathbf{R}}$ directly together!!!



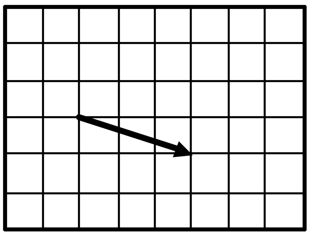
Box A



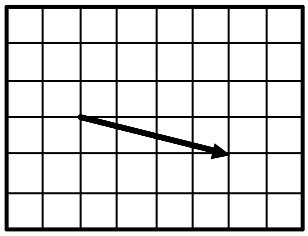
Box B



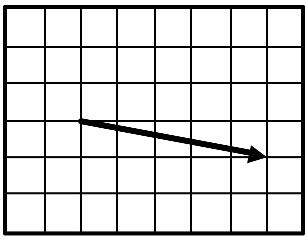
Box C



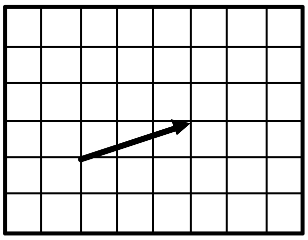
Box D



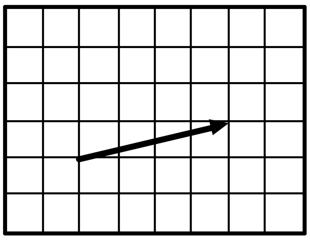
Box E



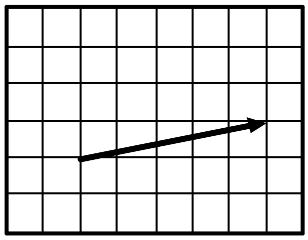
Box F



Box G



Box H



Possible answers. Select the best one.

A. Box **A** has the correct vector $\vec{\mathbf{2}}$

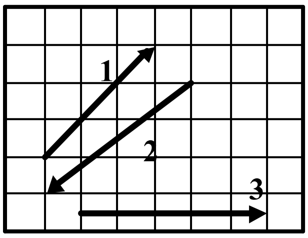
B. Box **B** has the correct vector $\vec{\mathbf{2}}$

C. Box **C** has the correct vector $\vec{\mathbf{2}}$

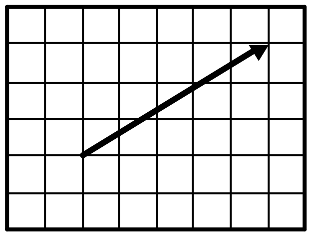
D. Box **D** has the correct vector $\vec{\mathbf{2}}$

E. Box **E** has the correct vector $\vec{\mathbf{2}}$
F. Box **F** has the correct vector $\vec{\mathbf{2}}$
G. Box **G** has the correct vector $\vec{\mathbf{2}}$
H. Box **H** has the correct vector $\vec{\mathbf{2}}$
I. None of the above has the correct vector $\vec{\mathbf{2}}$

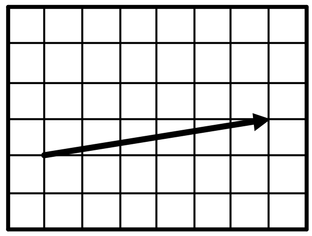
8. In the figure below are given three vectors $\vec{\mathbf{1}}$, $\vec{\mathbf{2}}$, and $\vec{\mathbf{3}}$. There exists a resultant sum, $\vec{\mathbf{R}}$, of the vector addition of the three component vectors (i.e., $\vec{\mathbf{R}} = \vec{\mathbf{1}} + \vec{\mathbf{2}} + \vec{\mathbf{3}}$). Find the best choice out of the given boxes below where the vector shown most closely resembles the correct resultant of the vector addition of the three component vectors.



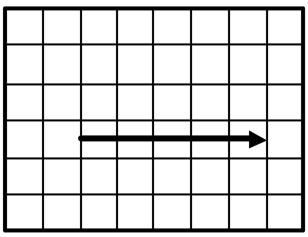
Box E



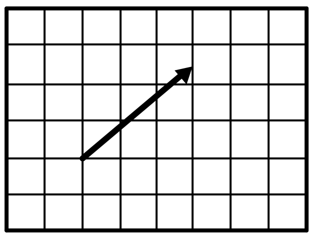
Box F



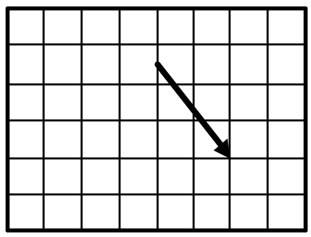
Box A



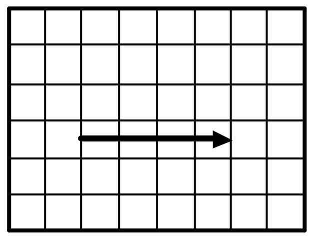
Box B



Box C



Box D



Possible answers. Select the best one.

A. Box **A** is the best choice for the resultant $\vec{\mathbf{R}}$.
B. Box **B** is the best choice for the resultant $\vec{\mathbf{R}}$.
C. Box **C** is the best choice for the resultant $\vec{\mathbf{R}}$.
D. Box **D** is the best choice for the resultant $\vec{\mathbf{R}}$.
E. Box **E** is the best choice for the resultant $\vec{\mathbf{R}}$.
F. Box **F** is the best choice for the resultant $\vec{\mathbf{R}}$.
G. None of the above. None closely resembles the correct resultant $\vec{\mathbf{R}}$.

Vertical Jump

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

Motion detector sensor
Tape
Mini trampoline (optional)
Spreadsheet

Procedure

Use tape to place the motion sensor on the ceiling. Stand immediately underneath the sensor and measure position vs time for each member of your group when they jump. Hold your favourite physics textbook firmly on top of your head to make a good reflecting surface.

Data Analysis

1. Use a spreadsheet to construct a displacement vs time graph and a distance vs time graph. On both graphs mark the following:

    - letter A on the point just before you began to jump
    - letter B on the point where you are crouched about ready to leap into the air
    - letter C where your feet have left the ground
    - letter D for the highest point of your jump
    - letter D where your feet have touched the ground again. but you are still moving down
    - letter E where you are landed and your motion momentarily stopped but your knees are still bent
    - letter F where you are standing motionless at the end of your jump

2. Use s spreadsheet to construct a velocity vs time graph for the interval when your feet were off the ground. Make a linear best fit graph and make an interpretation of the gradient and the intercept with the second axis.

3. Make a speed versus time graph.

4. Use the data to estimate the force exerted by the legs during the pushoff and landing.

Questions

1. What was your maximum height off the ground?

2. What is your hangtime?

3. What is your acceleration while you are in the air? What should it be theoretically? Discuss errors in the experiment.

4. On your velocity versus time graph mark the moment when you were in the air, but motionless. What was your acceleration at that moment?

5. How long did it take for your body to be motionless after your toes touched the ground on the way down?

6. How does mass affect the acceleration of someone jumping vertically?

Vibrating Meter Stick

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	Factors affecting the period of oscillation of a cantilever.

Experimental task

The aim of this experiment is to investigate the factors that affect the period of oscillation of a (wooden) meter stick securely clamped to a bench. The free end of the meter stick will in general have a fixed mass taped to it.

You are supposed to support your conclusion by using two different measuring techniques. Choose two of the following three possible sensors:

- light intensity probe/laser pen
- microphone probe
- motion detector probe

Visual Photometry

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Part 1 - Theory of the Bunsen grease-spot photometer

The Bunsen grase-spot photometer, invented in 1843, is a simple apparatus for making visual brightness comparisons: Between two light sources is a white paper with an oily spot. When the paper is illuminated from the front, the grease spot looks dark compared to the paper. When the paper receives equal illumination from front and back, the spot disappears and the luminous intensities satisfy

$$\frac{I_{V_1}}{I_{V_2}} = (\frac{d_1}{d_2})^2$$

where d_1 and d_2 are respectively the distances from the sources to sources 1 and 2.

Experiment 1

Make an experiment that compares the luminous intensities of a candle, a 40W light bulb, a 60W light bulb, and a 100W light bulb.

Part 2 – Spectral sensitivity of the human eye

Based on experiments on human observers the sensitivity of the human eye for various wavelengths were measured in the 1920s. The eye of an "average" human turns out to be most sensitive to brightness at $\lambda = 555\text{nm}$ (yellow) when the eye is adapted to moderate-to-bright light. When the peak is normalized to 1 the sensitivity curve $V(\lambda)$ shows the spectral sensitivity as a function of wavelength.

Data analysis

Use the data from http://cvrl.ioo.ucl.ac.uk/index.htm to make a plot of the visibility in Graphical Analysis. Would a normal distribution

$$\frac{1}{\sqrt{2\pi\sigma^2}} \cdot e^{-(\lambda-\mu)^2/(2\sigma^2)}$$

be a good fit? Explain how the theory above determines μ and σ and compare this curve with the experimental data.

References

[1] Nathaniel R. Greene, "Shedding Light on the Candela", The Physics Teacher, Vol. 41, Oct. 2003, pp. 409 – 414.

Weight vs Mass

Syllabus reference	
Date delivered out	
Aim	Investigate the difference between mass and weight

Statement of problem

Plan and execute an experiment that investigates the relation between weight and mass.

There are two constraints you have to follow: The data collection must involve the force probe and the data analysis must involve a linear best fit determination.

Part II

Various Lab Forms

Internal Assessment Marking Scheme

Name: ______________________

Legend for achievement levels: "c" – aspect fulfilled completely; "p" – only partially fulfilled; "n" – insufficient/not at all.

Criterion	Required Aspects			Level
Planning (a):	Identifies a focused problem or research problem. **c p n**	Relates the hypothesis or prediction directly to the research question and explains it, quantitatively where appropriate. **c p n**	Selects the relevant independent and controlled variable(s). **c p n**	**ccc: 3** **ccp, ccn, cpp: 2** **ppp, cpn, cnn, ppn: 1** **pnn, nnn: 0, NE**
Planning (b):	Selects appropriate apparatus or materials. **c p n**	Describes a method that allows for the control of the variables. **c p n**	Describes a method that allows for the collection of sufficient relevant data. **c p n**	**ccc: 3** **ccp, ccn, cpp: 2** **ppp, cpn, cnn, ppn: 1** **pnn, nnn: 0, NE**
Data Collection:	Records appropriate raw data (qualitative and/or quantitative), including units and uncertainties where necessary. **c p n**	Presents raw data clearly, allowing for easy interpretation. **c p n**		**cc: 3** **cp: 2** **cn, pp: 1** **pn, nn: 0, NE**
Data Processing & Presentation:	Process the raw data correctly. **c p n**	Presents processed data appropriately, helping interpretation and, where relevant, takes into account errors and uncertainties. **c p n**		**cc: 3** **cp: 2** **cn, pp: 1** **pn, nn: 0, NE**
Conclusion and Evaluation:	Gives a valid conclusion, based on the correct interpretation of the results, with an explanation and, where appropriate, compares results with literature values. **c p n**	Evaluates procedure(s) and results including limitations, weaknesses or errors. **c p n**	Identifies weaknesses and states realistic suggestions to improve the investigation. **c p n**	**ccc: 3** **ccp, ccn, cpp: 2** **ppp, cpn, cnn, ppn: 1** **pnn, nnn: 0, NE**

Date: ______________________

Lab title: ______________________

Topic/Option: ______________________

Manipulative Skills: **NE 0 1 2 3**

Personal Skills (a – TEAM): **NE 0 1 2 3**

Personal Skills (b – SELF): **NE 0 1 2 3**

XX

Name of Lab

LAB TEAM:

Names

INVESTIGATION TYPE:

DC+DA+PLA+PLB+
EV

DATE:

dd/mm- yy

SYLLABUS REFERENCE

X.X

Insert image here

Part II

Extended Essays

General Resources for Extended Essays

Books - general

In addition to the books mentioned here, see also the book resources on demonstrations.

C.L. Stong, *The Scientific American Book of Projects for the Amateur Scientist*, Simon & Schuster 1960.

J. Walker, "The Flying Circus of Physics With Answers", John Wiley & Sons, New York 1977, ISBN 0-471-02984-X.

Books – experimental techniques

Dinsdale and Moore, *Viscosity and its Measurement*, Reinhold Publishing, New York 1962.

Journals

American Journal of Physics
European Journal of Physics
Physics Education
The Physics Teacher

In particular will dimensional analysis probably be a useful tool:
J. F. Price, "Dimensional analysis of models and data sets", American Journal of Physics, Vol. 71, May 2003, p. 437.

The Frequency Dependence of the Coefficient of Attenuation in Air

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	An introduction to a possible topic for an Extened Essay

Equipment

Variable tone generator
Microphone sensor
Data analysis program with possibility for FFT analysis

Theory - Attenuation of air

If the energy of a spherical sound wave were conserved, the magnitude of the intensity would be inverse proportional to the distance from the source squared. However, due to absorbtion of energy by air, an exponential factor has to be included. In terms of the attenuation coefficient α and the initial intensity I_0 of the wave, the intensity I measured at a sufficient long distance R from the source is $I = I_0 e^{-\alpha R} / (4\pi R^2)$.

Experimental setup

In order to prevent unwanted reflections, the experiment was done in a room with sound absorbing walls and ceiling with chairs and tables isolated in a corner.

A variable tone generator was placed on the floor beneight a microphone attached to the ceiling via a solid rope. The readings from the microphone were sampled with a computer and shown graphical by the MultiPurpose Lab Interface program (Vernier Software and Technology [5]).

The frequencies were chosen to satisfy three criteria: First of all they should be much larger than the fundamental frequency of the room itself (60Hz – fundamental frequency of a standing wave in my lab). Secondly they should be below the half of the samling frequency (with my equipment 100kHz) by the Nyquist theorem (reference [2] p. 234). Finally, the frequencies should have a strongly dominating peak in the FFT Window of the MultiPurpose

Lab Interface program with neglible noise. Consistent with these criteria were the frequencies 3kHz, 8kHz, 10kHz, 15kHz and 20kHz.

Measurements and analysis

For each frequency, the gauge pressures vs time was sampled for 0.12s at seven different heights and for each height ten repeated measurements of the gauge pressure vs time was made.

The intensity (up to a normalization constant) is then given as the time average of the square of the gauge pressure. By averaging every group of ten intensities based on measurements at the same height and with the same frequency, we got relative uncertainties below 10%. Further, for each of the five frequencies, the coefficients of attenuation were obtained from the gradient of $\ln\left(4pR^2 \cdot I\right)$ vs R. At the end we could make the log-log plot of coefficient of attenuation versus frequency in MultiPurpose Lab Interface. The resulting graph (see figure 1) shows a reasonable straight line with gradient approximately 1.7, reasonable close to the theoretical expected result 2.

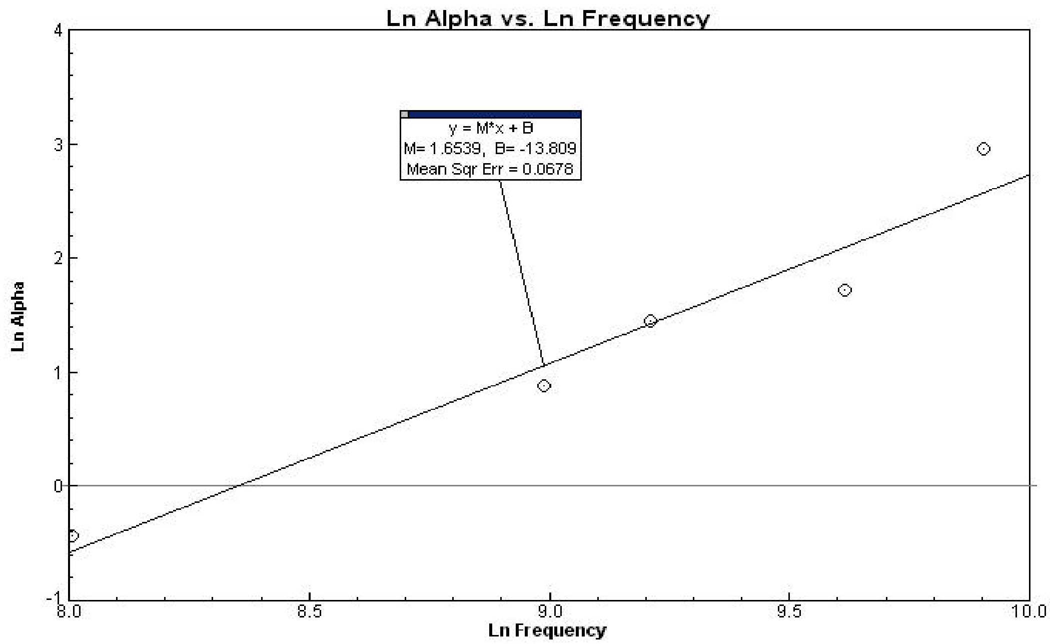


Fig 2. A log-log plot to determine the exponent of the frequency

More information

This idea was part of a larger Extended Essay. The student has given his own account of the Extended Essay on the web (part of the national *Unge Forskere* competition) at

http://www.unge-forskere.no/konkurransen/2001/prosjekt/michael_le.shtml

Acknowledgement

Thanks to Michael Huy Lee for supplying the data from his Extended Essay.

The Physics of Tuning a String Instrument

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	

Equipment

A string instrument
Microphone sensor

Motivation

Most students have an interest in music. In fact, many of them can play at least one instrument when they enrol to their first physics course. What would then be more appropriate than to do an Extended Essay based on their favourite instrument? This note describes some ideas of and some results obtained by a previous student of mine who chose her Hardanger fiddle[1] (see figure 1) as the object of her experiments. Even though some of the minor details are specific for this instrument, the main ideas can be applied for any string-based instrument.

The Hardanger fiddle has been developed from the standard violin. A basic difference from the violin is four to five resonance strings (in this case five) below the four upper main strings (called the Kvint, the Ters, the Kvart, and the Bass). An interesting practical problem confronting fiddlers arises in the process of tuning one of these strings: How much does this tuning change the frequencies of the other strings?

Preparation, set-up and procedure

A week before the experiments started new string were set on the fiddle, giving the fiddle time to settle into a state of equilibrium. The Hardanger fiddle was then tuned to the most common tuning, “oppstilt”. Further, one day before the experiment the fiddle was left in the lab fixed within a wooden contraption (see figure 1) in order to adjust to temperature and humidity conditions as well as securing the same forces to act on the fiddle during the

[1] This instrument is number 284 made by Bjarne Øen from Bø in Telemark.

experiments. A computer with a Vernier MultiPurpose Lab Interface (MPLI) and a microphone was set up in order to measure frequency.

Fig. 1. Experimental setup: The four main strings are from top to bottom called Bass, Ters, Kvart, and Kvint. The no visible resonance strings below the main strings are ordered from the bottom to the top, i. e., the first resonance string at the bottom and the fifth resonance string at the top.

The following procedure was followed for each string: Start with the “oppstilt” tuning (we will from now on call it state 1) and measure the fundamental frequency for each string. Then stretch the string under investigation a bit and measure the frequencies for each string for this new state (state 2). This procedure of stretching and measuring is repeated up to and including state 4. Finally relax the string back to approximately where it started (state 5). In order to obtain as accurate values as possible this cycle from state 1 to state 5 was repeated three times and an average value for each state was obtained. All deviations from the mean were less or equal 0.5Hz. The amount of stretching was attempted to be uniform by twisting the same angle for each state change.

Results for fundamental frequencies and discussions

In figure 2 the frequencies of the Kvint in the five states defined in the previous section is shown. There is a clear tendency for the frequency of the Kvint to decrease for all tunings and the final state five is reasonable close the initial state for all tunings. The same pattern was observed when plotting the frequencies of the other three strings for various tunings.

On the other hand, according to figure 2 the change of frequency of the Kvint string is clearly more sensitive to tuning of the Kvart and Ters strings than to the Bass string.

A similar picture emerges when the resonance string frequency is plotted for various tunings. Figure three shows how the fifth resonance frequency changes with the various states. In this case the Bass string tuning has the strongest influence on the frequency of the fifth resonance string.

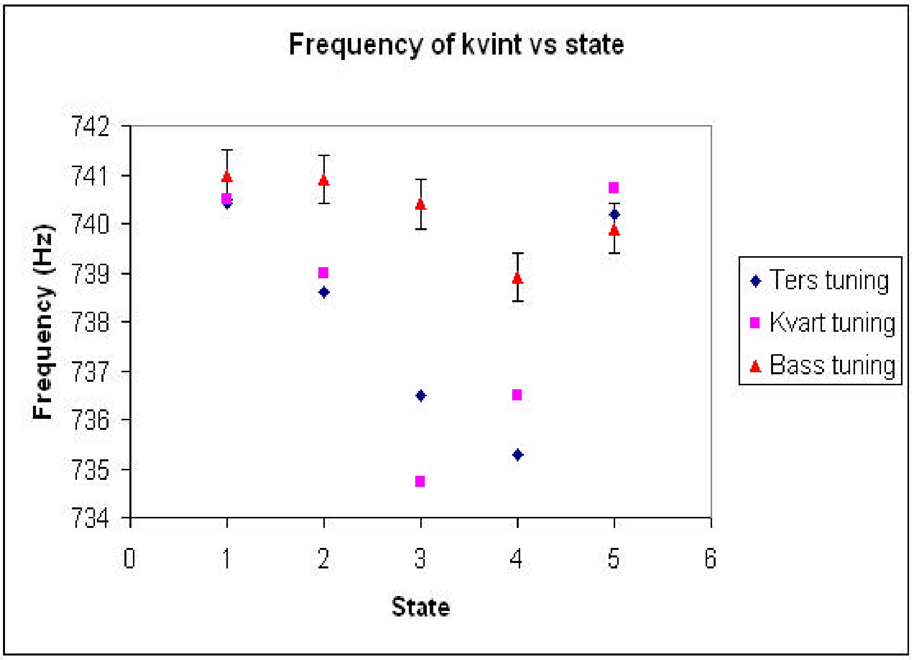


Fig 2. For easy reading the uncertainty bars have only been put on the data from the Bass tuning. All points have the same uncertainty.

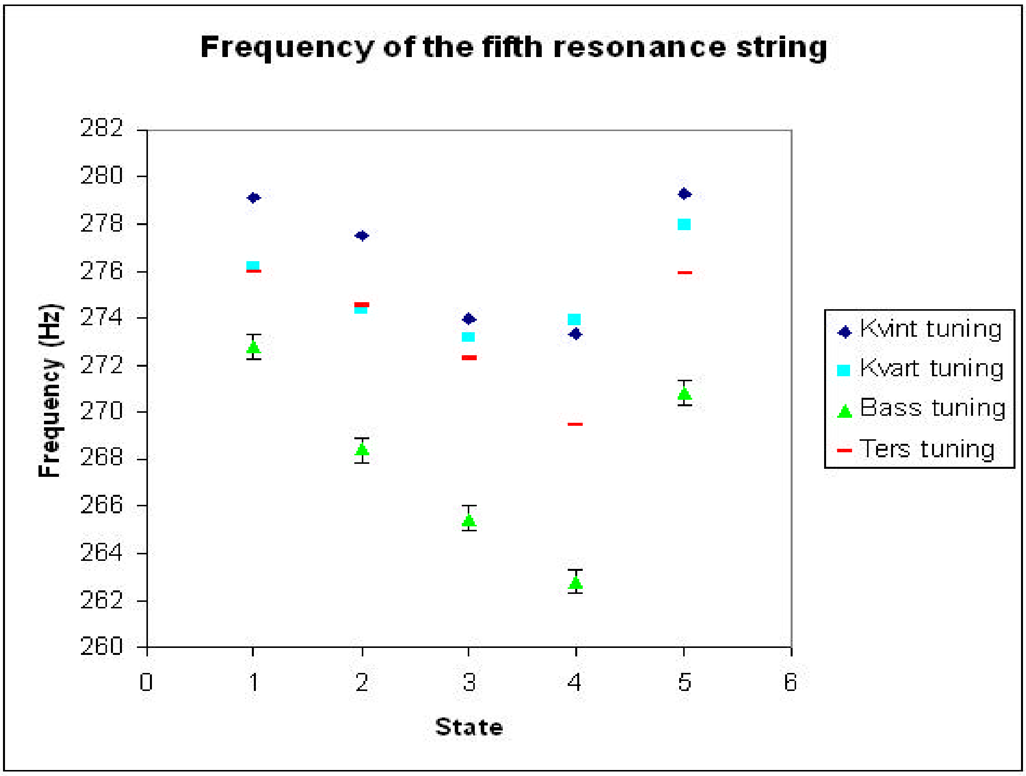


Figure 3. For easy reading the uncertainty bars have only been put on the data from the Bass tuning. All points have the same uncertainty.

Some suggested results

The tuning of one of the main strings on a Hardanger fiddle changes the frequencies of the other main strings as well as the frequencies of the resonance strings.

However the amount of coupling between the strings is not uniform. This shows that certain sequences of tuning will lead to better results than others for a given number of tunings.

Some possible extensions

One extension of this experiment would be to measure the change in geometry of the fiddle during tuning by placing small bits of a mirror on various places on the surface of the fiddle (for instance by using clay) and measure changes in the end position on the wall of a laser beam that starts from an external laser source and reflects via such a mirror. In particular the bridge should be affected when tuning the fiddle. This was confirmed by some measurements and the results were very dependent on which tuned string one used. An interesting observation during the experiments was that it took approximately five minutes from having tuned a string to the reflected beam did stabilise at one point at the wall. Obviously the twisting of the bridge has components in all spatial directions, so a full investigation would be challenging indeed.

Another obvious extension is to examine what happens to the higher order harmonics when tuning the fiddle.

More information

The student has given her own account of the EE on the web (part of the national *Unge Forskere* competition) at

http://www.unge-forskere.no/konkurransen/kuf99/prosjekt/99_64.html

Acknowledgement

Thanks to Kirsten Haaland for giving me access to her experimental data and for letting me use the photograph of her fiddle.

Acoustic Lensing by a Paraboloid

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	An introduction to a possible topic for an Extened Essay

Equipment

Paraboloid
Michrophone sensor
Meter stick
Sound source with variable frequency

Introduction

When demonstrating the law of light ray reflection in geometrical optics, many instructors mention applications like paraboloid mirrors behind frontal light bulbs in cars. Knowing that geometrical optics is a high frequency limit of the wave theory of light, by analogy it is natural to inquire if it is possible to demonstrate a similar effect in acoustics for a sufficient high frequency. Due to the fact that sound intensity decreases rapidly with the distance from the source while the light intensity of a laser beam is pretty constant (on a physics lab length scale), it seems reasonable to expect the geometrical focal point to differ from the acoustical one.

Experimental setup

A possible acoustical version of the light demonstration in the previous section is shown in figure 1: The source is placed on the parabolic axis of symmetry at a distance much larger than the wavelength of the generated sound. The microphone can move along the same axis with the opening pointing downwards.

Fig. 1. Set-up

A Simple Simulation

In the high frequency case the equations of the ray approximation of acoustics [1] were simulated with parallel incomming rays and with correct dimensions of the paraboloid using the computer algebra system Derive. As seen in figure 2 there should be an axial maximum at 12 cm.

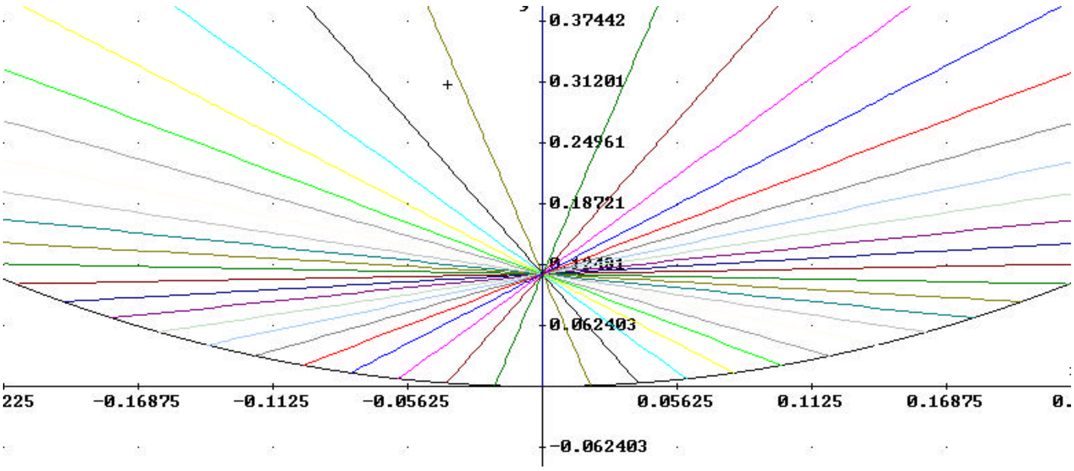


Fig. 2. Reflected rays for the planar case

Results - Axial

For the axial case with frequency 2000 Hz, the experimental intensity (normalized with respect to the intensity at 12 cm) seems to be close to the theoretical result as indicated in figure 3.

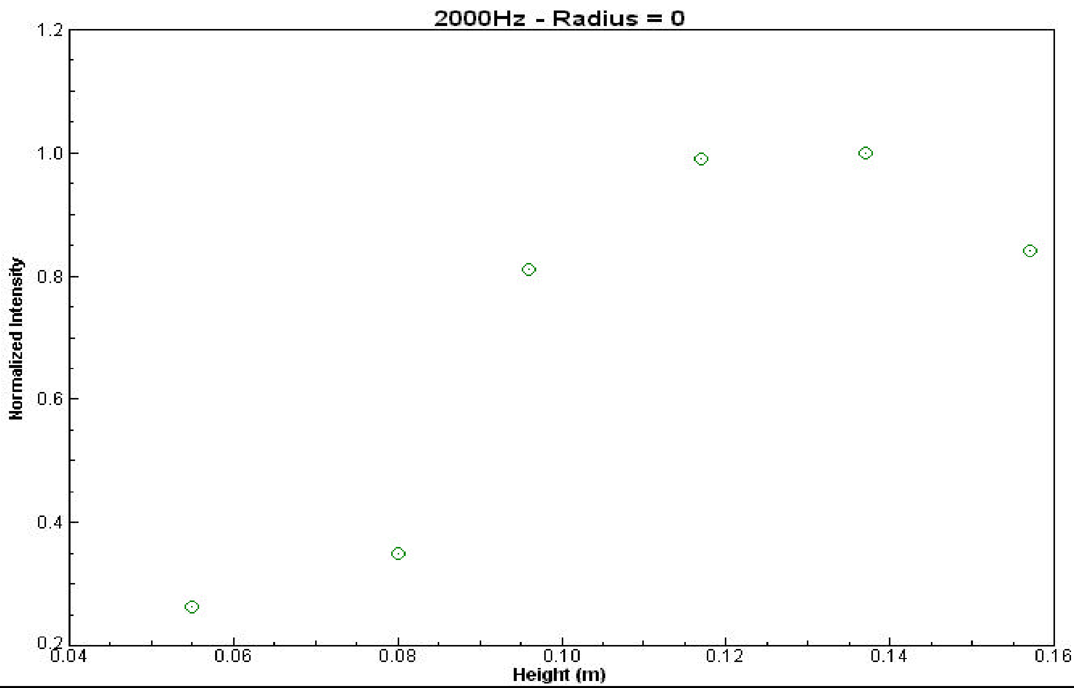


Fig. 3. Experimental normalized intensity – frequency 2000 Hz.

At a higher frequency (8000 Hz) the top of the intensity is sharper and occours at a higher height:

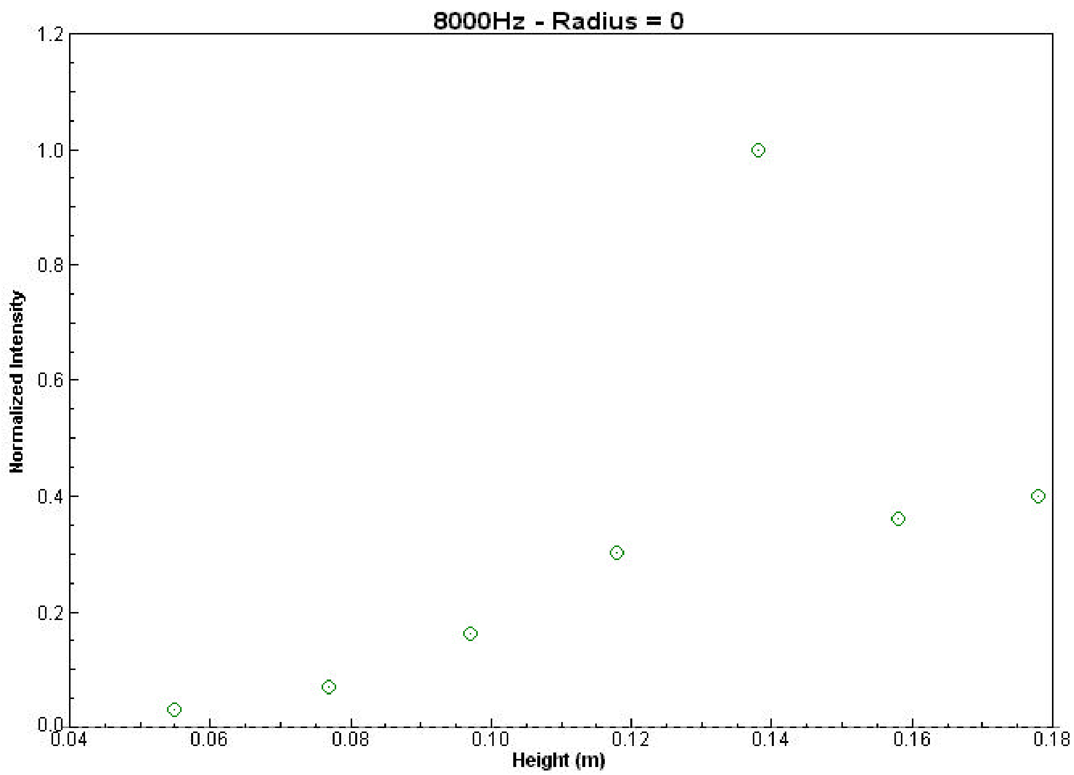


Fig. 4. Experimental normalized intensity – frequency 8000 Hz.

Other results

With a source frequency of 6000 Hz a resonance frequency of 18000 Hz was measured with the FFT window, exactly 3 times larger than the original frequency. This can be explained in terms of fundamental frequencies as the dish behaves similarly to a tube with one end closed.

The relative intensity was also measured at 10000 Hz as a function of both height and radius. For a fixed radius, the intensity as a function of height has a top pointas indicated in figure 5.

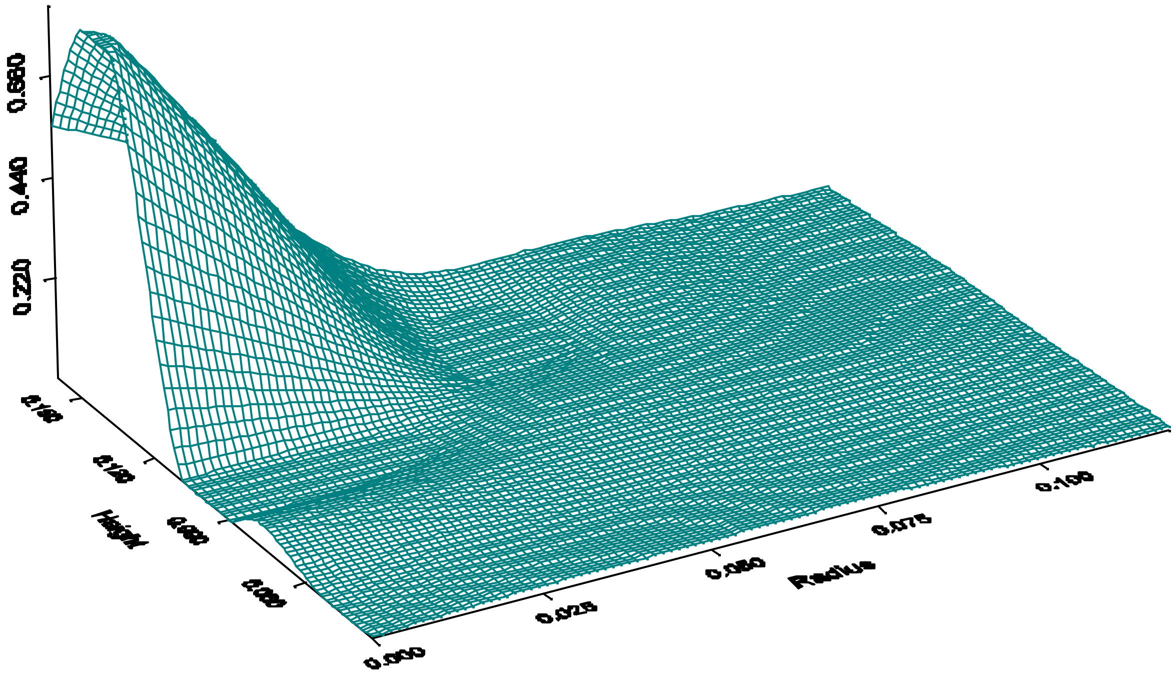


Fig. 5. Relative intensity as a function of height and radius

Conclusion

The experimental values and the theoretical model coincided surprisingly well for all frequencies for radius equal zero. As the microphone gets further away from the axis of the dish the uncertainty of the model gets worse. There is also a trend in how well the model fits the different frequencies, the higher frequencies (many not shown here) giving better results.

Reference

[1] Pierce, Alan D., *Acoustics – An Introduction to Its Pysical Principles and Applications*, Acoustical Society of America.

Physics EE Case IV

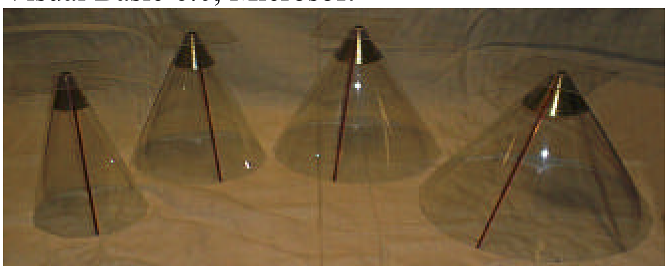
Resonance Frequency Spectrum of Axial Symmetric Cavities

Syllabus reference	
Assessment Criteria	
Date delivered out	
Date for handing in	
Aim	An introduction to a possible topic for an Extened Essay

Equipment

Software:
MPLI program for windows, Vernier Software
Graphical Analysis for windows, Vernier Software
Axum 6.0, MathSoft
Excel 2000, Microsoft
Visual Basic 6.0, Microsoft

Cones with angles 15º, 20º, 25º and 30º left to right:



Four cylinders with diameters 160mm, 100mm, 80mm and 63mm, left to right:

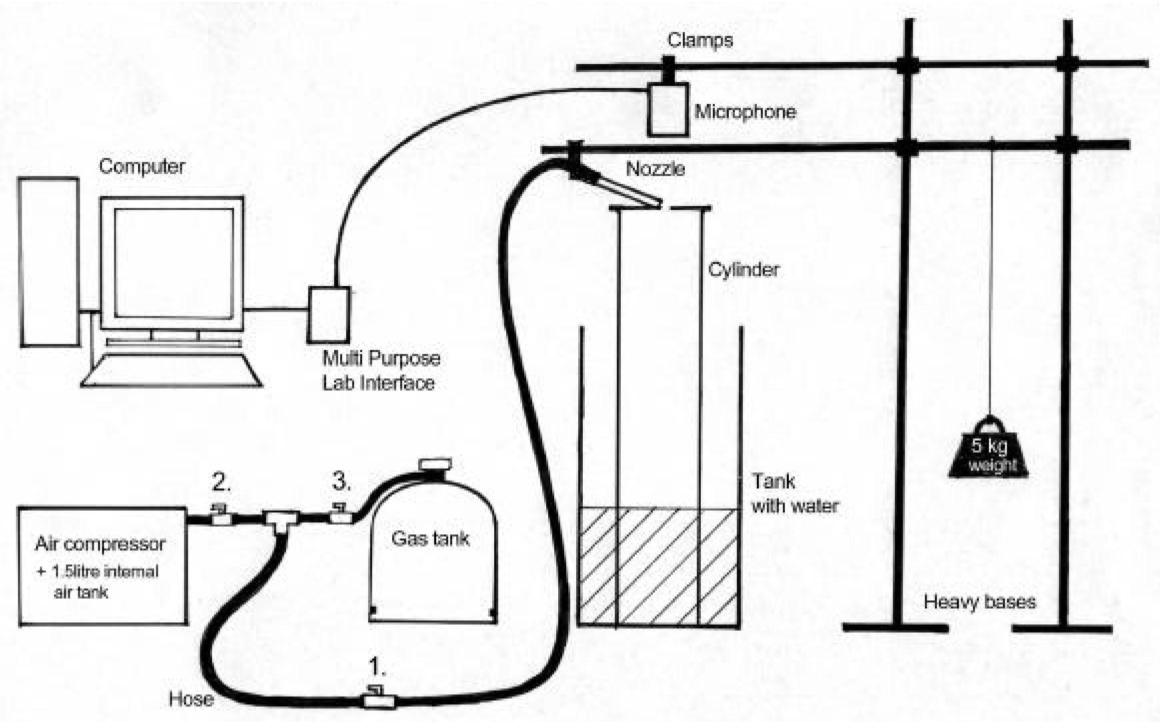
Other:
6 bar air compressor - 1.5 litre air tank
14 litre gas tank
T-joints, air valves
Stands, clamps, metal bars
Various containers
Garden hose
Computer with ”Multi Purpose Lab Interface” (MPLI)
Microphone for MPLI, Vernier
Tone generator, tuning forks

Research Question

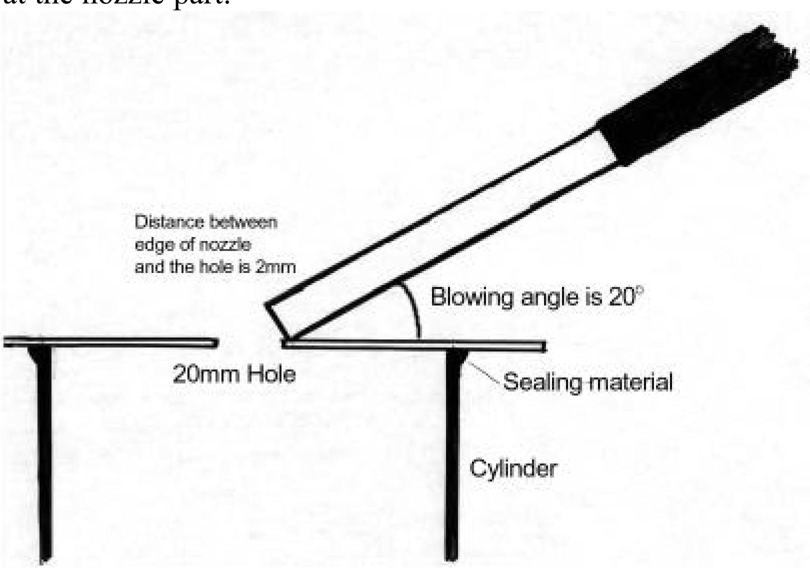
How does the resonance frequency spectrum of axial symmetric cavities depend on material and the geometry of a cavity?

Experimental set-up

A simple way to vary the height is to put the cavity in a tank and fill the tank with water. For a cylinder the set-up would be as follows:



A closer look at the nozzle part:



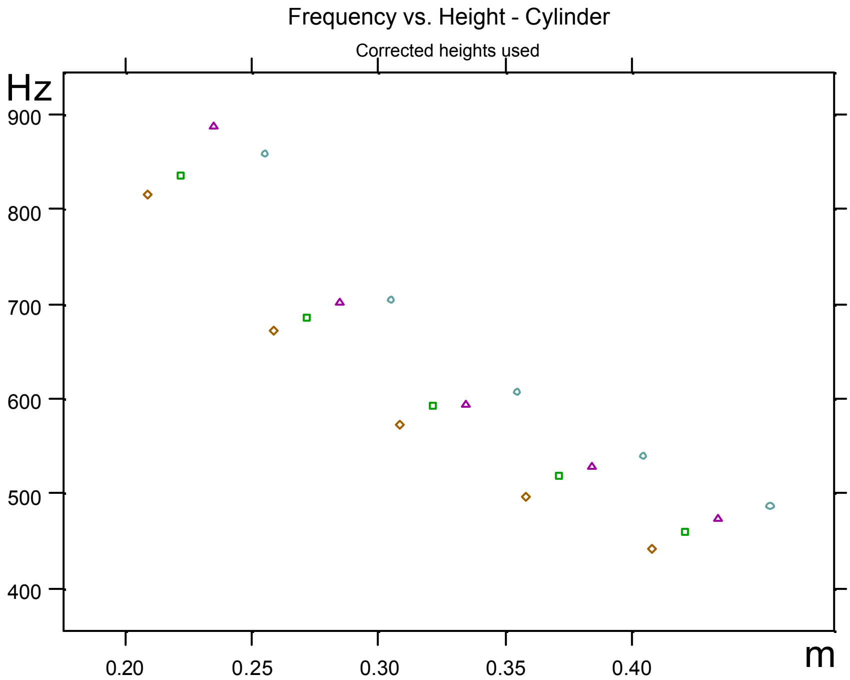
Experimental procedure (see picture above)

The air compressor is turned on. To fill the gas tank valve (1) is closed while valve (2) and (3) are open. When the gas tank pressure reaches 4 bar, the compressor switches off. Valve (2) should only be open whilst filling the gas tank, ensuring that the air compressor does not switch on when the air pressure sinks, creating background noise.

1. Check gas tank pressure is at 4 bar, and compressor turned off.
2. Check the angle of the nozzle has not altered.
3. Activate the MPLI program by pressing "Start", wait 2 seconds for the program to initiate.
4. Open valve (1) long enough to complete the recording, and then close it.
5. Open valve (2) to refill the gas tank.
6. Register the result:
   a. Register the following information in MPLI Text Window in a table:
      - Type of experiment
      - Cylinder / cone material, diameter/angle and height
      - Date
      - Temperature
   b. Choose *Save as...* and find a suitable filename

Fill the gas tank and repeat steps 1–6 for each test. To avoid one bad reading affecting the results, try to take 3 good recordings on each level before adjusting the level.

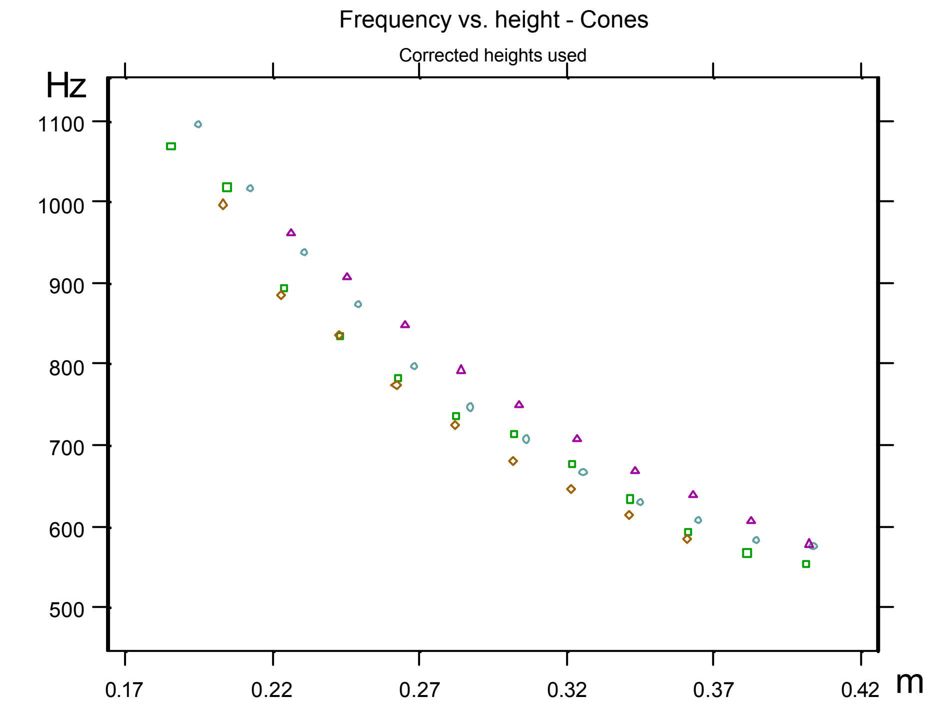
Results – Raw data



Graph 5.2.1

o 63mm diameter cylinder ? 80mm diameter cylinder

? 100mm diameter cylinder ? 160mm diameter cyinder



Graph 5.2.2

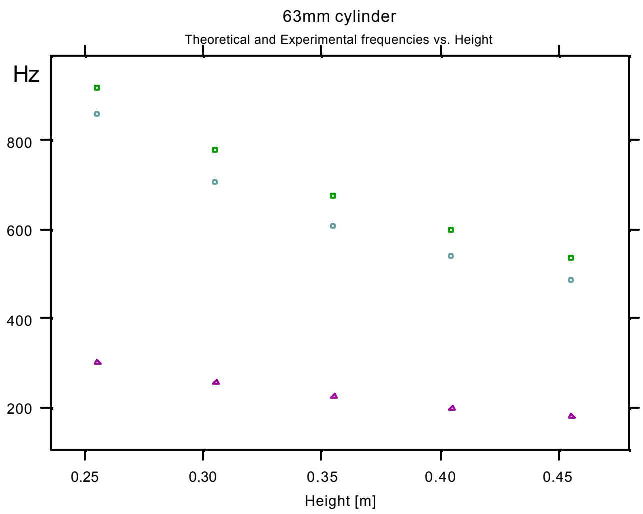
o 15º cone ? 20º cone ? 25º cone ? 30º cone

Theoretical model - cylinder

For axial modes of cylinders the wave number k satisfies the equation

$$\tan kL \tan kL_0 = \frac{A}{A_0}$$

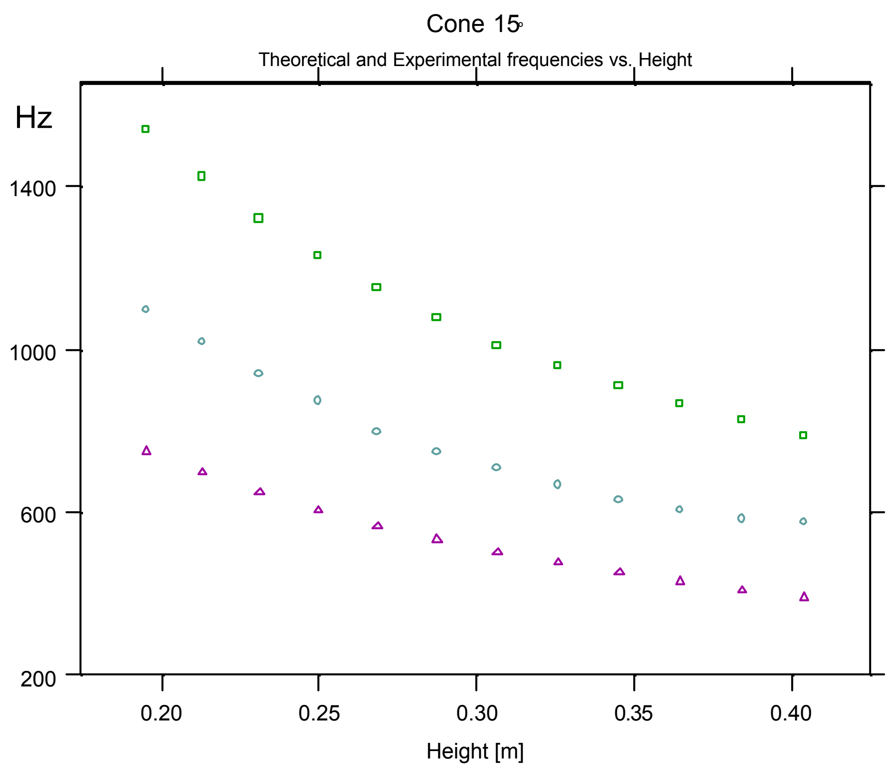
where L, A and L_0, A_0 are the length and radius of the neck and the cavity respectively.
A graphical presentation of this vs. the experimental data (graph 5.4.1) shows us that the first theoretical frequency was much lower than the experimental one. However, the second theoretical frequency proved to be very close:



o Experimental frequencies ? First theoretical frequency ? Second theoretical frequency

Theoretical model - cones

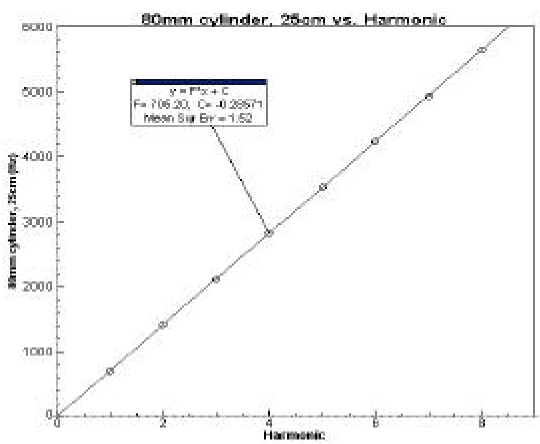
A model was derived from the general axial formulae (Crawford88) page 710. The result is $\tan(kH) = kR/\tan\alpha$ where H is the height, α the cone angle, and R is the bottom radius. Results from the two first theoretical frequencies for the axial modes:



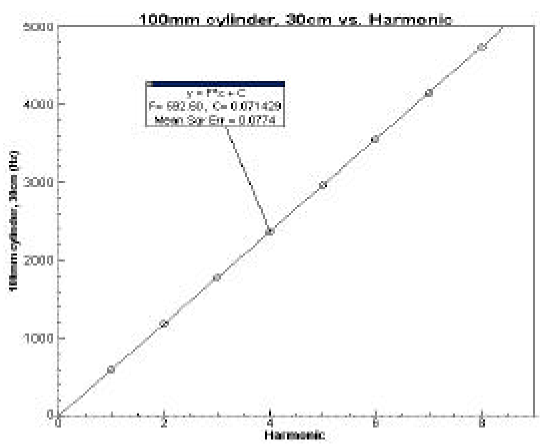
o Experimental frequencies ? First theoretical frequency ? Second theoretical frequency

The results were very much like the cylinders; the second theoretical frequency was closer to the experimental, while the first theoretical was too low. The form of the experimental and theoretical graph curves is very similar for both cylinders and cones.

Results – Overtones for Cylinder

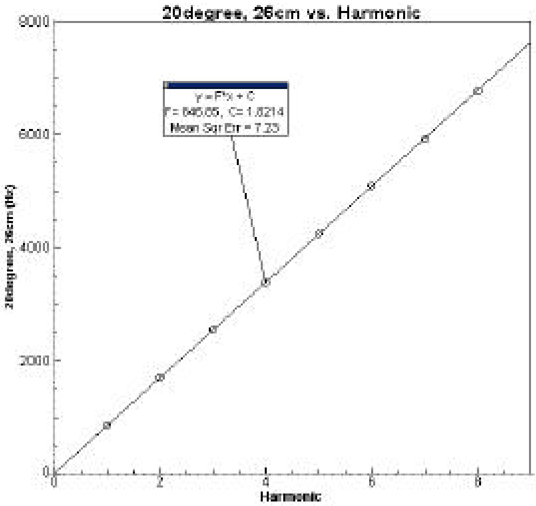


Overtone example; 80mm cylinder, 25cm high

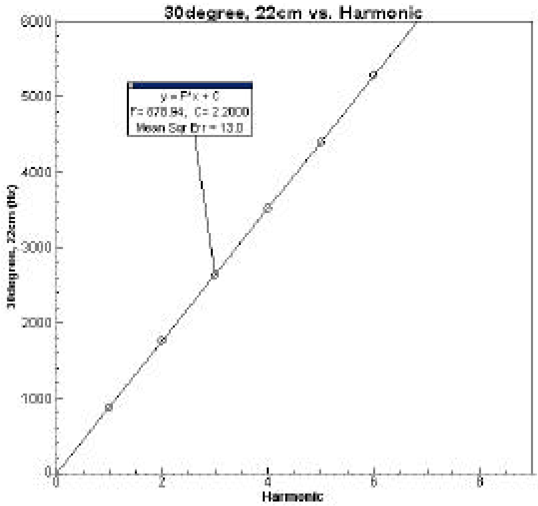


Overtone example; 100mm cylinder, 30cm high

Results – Overtones for Conics



Overtone example; 20degree cone, 26cm high



Overtone example; 30degree cone, 22cm high

Extensions

- Include end correction
- The water being displaced by the compressed air created the most visible problem in my --research, making it difficult to find the active height of the cavity. If decreasing the air pressure still produced clear results, this would probably reduce height deviation. Alternatively, holding the air pressure constant, and reducing the air volume by decreasing the nozzle size. This would increase the hissing sound, which would hopefully be easily identifiable on the gathered data.
- An idea for further investigation would be to study the air movement within the cavities, and learn more about the different factors influencing the resonance frequency. This could possibly be explored by using coloured smoke or very light tell-tail tassels fastened inside the cylinders.

More information

This idea was part of a larger Extended Essay. The student has given his own account of the Extended Essay on the web (part of the national *Unge Forskere* competition) at

http://www.unge-forskere.no/konkurransen/2001/prosjekt/michael.shtml

Acknowledgement

Thanks to Michael Alexander Calder for supplying the data from his Extended Essay.

References

F. S. Crawford, *Lowest modes of a bottle,* American Journal of Physics 56 (8), August 1988, pp 702 – 712.

M. Alster, *Improved Calculation of Resonant Frequencies of Helmholtz Resonators*, Journal of Sound and Vibration, 24 (1), 1972, pp. 63 – 85.
A. Selamet and P. M. Radavich, *Circular Concentric Helmholtz Resonators*, Journal of the Acoustical Society of America, 101 (1), January 1997, p. 41.

Other Ideas

Topic	Culvert whistlers
Sensor(s)	Microphone
Tool(s)	Cylinder and sound source
Idea & procedure	A source is placed at one end of a cylinder and the microphone at the other. Initially the investigation is done on-axis, but if the student has time and ambition enough, the investigation can be extended to off-axis. Given a source of a "pure" frequency, how do the radius and length of the cylinder affect the frequency spectrum? Similar question can be asked about the intensity of the sound. The results should be compared with free space measurements.
References	F. S. Crawford, *Culvert whistlers revisited*, American Journal of Physics, Vol. 56, Aug. 1988, p. 752. E. A. Karlow, *Culvert whistlers: Harmonizing the wave and ray models*, American Journal of Physics, 68, June 2000, p. 531 – 539. C. L. Adler, K. Mita, and D. Phipps, *Quantitative measurement of acoustic whistlers*, American Journal of Physics, July 1998, pp. 607 – 612. K. Meykens, B. Van Rompaey and H. Janssen, *Dispersion in acoustic waveguides—A teaching laboratory experiment*, American Journal of Physics **67** (5), May 1999, pp. 400 – 406.

Topic	Tuning Forks
Sensor(s)	Microphone
Tool(s)	
Idea & procedure	
References	P. P. Ong, *Little known facts about the common tuning fork*, Physics Education, November 2002, pp. 540 – 542. R. J. Stephenson, *Mechanics and Properties of Matter*, New York, Wiley 1969

Topic	Characteristics of Reflected Light
Sensor(s)	Light Intensity Probe
Tool(s)	Polarization filters
Idea & procedure	If unpolarized white light is reflected from a glass plate or a blank metalic sheet, some of the light is reflected depending on the angle of incidence. What if we measure the degree of polarization before and after? What if we use red laser light? For transparent materials like glass/acryl, how does the reflection coefficient compare to the coefficient of transmission?
References	P. J. Ouseph, *Polarization of Reflected Light*, The Physics Teacher, Volume 40, Oct. 2002, pp. 438 – 439.

Examples of Use of Excel VBA in Extended Essays

The code below is taken from the Extended Essay "Radiation from a tuning fork" written by Frank Skavland. The first example shows how data from data analysis software can be transferred to spreadsheets and the second example shows how to implement calculation algorithms in spreadsheets. In practice the actions were first recorded as Word macros and then tuned.

```
' For each EXP file in a given folder, the data are inserted into a sheet
Sub Read_MPLI_File()
        Dim myFile, Folder, Message, Title, Default, FileGroup as String
        Sheets.Add
        Mes = "Enter complete path of folder"
        Title = "Getting information on folder name"
        Default = "C:\MyExpFiles"
        Folder = InputBox(Message, Title, Default)
        ChDir Folder
        FileGroup = Folder & "\*.EXP"
        myFile = Dir(FileGroup)
        Do While myFile <> ""
            Workbooks.OpenText FileName:=myFile,_
                Origin:=xlWindows, StartRow:=119, DataType:=xlDelimited, TextQualifier:=xlDoubleQuote,_
                ConsecutiveDelimiter:=False, Tab:=True, Semicolon:=False, Comma:=False, Space:=False,_
                Other:=False, FieldInfo:=Array(Array(1,1), Array(2,1), Array(3,1),Array(4,1), Array(5,1))
            Range("A1811:E1833").Select
            Selection.ClearContents
            ActiveWindow.SmallScroll Down:=-3
            ActiveWindow.ScrollRow = 1
            Range("A1").Select
            Sheets.Add
            myFile = Dir
        Loop
End Sub
```

Excel VBA code for transferring data from MPLI files to spreadsheets

```
Sub CalculateTimeAverage()
        Dim i, j As Integer
        Dim Sum, Mid, a, b, c, d As Double
        Range("G2").Select, ActiveCell.Value = "Calculated time average of gauge pressure squared"
        Range("H4").Select, ActiveCell.Value = "Time"
        Range("I4").Select, ActiveCell.Value = "Average"
        For i = 1 To 5
                Sum = 0
                For j = 1 To 361
                        a = CDbl(ActiveSheet.Cells(362*i-360+j-1,1).Value)
                        b = CDbl(ActiveSheet.Cells(362*i-361+j -1,1).Value)
                        c = CDbl(ActiveSheet.Cells(362*i-360+j -1,5).Value)
                        d = CDbl(ActiveSheet.Cells(362*i-361+j -1,5).Value)
                        Sum = Sum + (a-b)*(c+d)/2
                Next j
                a = CDbl(ActiveSheet.Cells(362*i-361,1).Value)
                b = CDbl(ActiveSheet.Cells(362*i,1).Value)
                Mid = (a+b)/2
                ActiveSheet.Cells(4+i,8).Value = Mid
                ActiveSheet.Cells(4+i,9).Value = Sum / (b-a)
        Next i
        Range("G11").Select, ActiveCell.Value = "Linear regression analysis"
        Range("H13").Select, ActiveCell.Value = "Gradient"
        Range("I13").Select, ActiveCell.Value = "Y intercept"
        Range("H14").Select, ActiveCell.FormulaR1C1 = "=STIGNINGSTALL(R[-9]C[1]:R[-5]C[1],R[-9]C:R[-5]C)"
        Range("I14").Select, ActiveCell.FormulaR1C1 = "=SKJÆRINGSPUNKT(R[-9]C:R[-5]C,R[-9]C[-1]:R[-5]C[-1])"
End Sub
```

Excel VBA code for calculating time average of gauge pressure squared by trapezoid integration.

Part III

Demonstrations

180 Demonstrations from PHYS-L

In the mailing list PHYS-L for physics teachers in general, both high school and university teachers participate, you may find many interesting demonstrations and ideas for labs. Herb Gottlieb (New York City) posted the 180 demonstrations below in two messages to this list. In order to bring them back from their state of limbo, being dug into a lot of less informative text, the gems are reproduced here. Very many of the demos seem to be original.

84 Demonstrations in physics

1P. ADIABATIC HEATING.

A considerable temperature increase occurs when a rubber band is stretched. Hold a thick rubber band against your upper lip and extend it quickly. Your lip can sense the increase in temperature. Allow the rubber band to contract rapidly and note that it suddenly becomes colder.

2P. AIR GLUE.

To demonstrate Bernoulli's principle, cut a circular piece of cardboard slightly larger than the end of a thread spool. Push a straight pin all the way into the center of the cardboard. Hold the spool so its hole is vertical. Press the cardboard against the bottom of the spool with the free end of the pin inside the bottom of the spool hole. Blow into the top of the spool hole. The air acts like glue and the cardboard clings tightly to the spool as long as there is air motion through the spool.

3P. AIR PRESSURE SUCKER.

Is so-called suction a push or a pull? Arrange a flask fitted with a two hole stopper and a glass tube extending well down into the flask which is completely filled with water. Challenge a good-natured student to "suck" water up the glass tube while the instructor holds a finger over the other hole of the stopper. When the student fails to get any water out of the flask, instructor might remark, "Jim is not as big a sucker as we thought." After appropriate comments and removing the finger from the stopper hole, the instructor asks the boy to try again. Suddenly the sucker succeeds. When the class becomes orderly again, explain how air pressure provides the necessary push.

4P. AIR PUCK.

Cut a six inch circle of plywood or press board. Cement a small cork at its center, Drill a very fine hole through the disc and cork. Inflate a balloon and fasten its mouth over the cork. Place the apparatus on a smooth surface to see almost frictionless motion on cushion of air.

5P. ANTI GRAVITY.

Select two test tubes so that one barely fits inside the other. Partly fill the larger with water and float the smaller one on the water. Quickly invert the tubes. As water leaks out, the smaller tube will rise, apparently defying gravity.

6P. BALL IN FUNNEL.

Blow or suck on the small end of a funnel containing a ping pong ball. The ball will not fall out even though the funnel is inverted, so long as air is moving between the ball and the funnel wall.

7P. BALLOON ELECTROSCOPE.

Light rubber balloons suspended from long silk strings act as demonstration electroscope. Charge the balloons by rubbing them with woolen cloth or fur. When charged, balloons can be made to stick to flat surfaces such as walls or ceilings.

8P. BERNOULLI BALANCING ACT.

Bernoulli's principle can be shown by balancing an inflated balloon or beach ball on a jet of air from the output end of a vacuum cleaner. The balloon will hover near the ceiling and will not fall off although tipped at a considerable angle. A ping pong ball balanced on a fine jet of water will illustrate the same.

9P. BIG TORQUE.

Hold the end of a broom handle in one hand and extend your arm and the broom handle horizontally in front of you. Tie a string around a book and hang the book under the stick a few centimeters from your hand. Try to keep the stick horizontal while someone slides the book toward the end of the stick. Although the weight of the stick and book do not change, the torque increases. Lever arm has real meaning here.

10P. BLACK BOX CONTENTS.

Into a small box, place small objects and seal box closed. Students can examine box, blindfolded, and tell you:

(a) How many pieces are in the box.
(b) The shape of the pieces.
(c) How heavy the pieces are (density).
(d) How big the pieces are.
(e) The color of the pieces.

By doing this the student has reason to believe that the scientists may know something about the atom even though it has never been seen; as he has not seen the objects in the box.

11P. BOILING WITH ICE.

Fill a flask two-thirds full of water and bring it to a boil. Cork the flask and invert it taking care that the hot water does not spill out. Place an ice cube on bottom of flask. As the ice melts, the water begin to boil again. If the flask is corked with a one-hole stopper with a glass tube extended almost to the bottom of the flask, boiling can be effected by reducing the

pressure of the entrapped air. You can also run cold water over the flask. Have the student feel the flask temperature as the ice boils the water. of boiling water.

12P. CHAIN REACTION.

Arrange wood matches closely on a soft board by means of straight pins placed through them at their midpoint. Hold the board upright and ignite the bottom match. The others will follow in turn to demonstrate a chain reaction.

13P. CHIEF SOHCAHTOH.

Sometimes it helps to point out that the sine of an acute angle in a right triangle is the side opposite over the hypotenuse; O/H, oh!. The cosine is "ah". A well known trick is to recall the name of the legendary American Indian physicist, "Chief Soh- cah-toa". (Sine is opposite over hypotenuse; cosine is adjacent over hypotenuse; and tangent is opposite over adjacent.

14P. COLOR ABSORPTION.

Using colored pencils, draw a bird in a blue cage. Let the bird out of the cage by covering the drawing with a red filter. Try other color combinations to show the effects of color absorption by filters.

15P. COLORED ROACHES.

Many organic substances, dead or alive, show interesting characteristics under black light. Cockroaches are multicolored under ultra-violet light.

16P. CONDENSATION OF WATER VAPOR.

A simple cloud chamber can be made from a gallon jug fitted with a one-hole stopper with a short piece of glass tubing. Blow into the jug through the glass tubing to increase pressure. Put finger over end of tube and pull stopper, suddenly reducing the pressure. No cloud is formed. If some smoke is introduced into the jug it provides nuclei about which water vapor condenses. Repeat the performance and watch the clouds form in the jug.

17P. COTTRELL PRECIPITATOR.

Attach one lead from a spark coil to foil surrounding a glass tube of about one-inch diameter. Extend a wire from the other terminal of the spark coil through the tube, insulated from the foil. Place a small amount of hydrochloric acid in one flask and some ammonium hydroxide in a second flask. With glass tubing connect the flasks and large glass tubing in train. Blow air into the first flask causing ammonium chloride to be forced into the Cottrell precipitator. Activate spark coil and see 'smoke' consumed. It works near instantly on cigarette smoke.

18P. CRUSHED CAN.

The force of normal external air pressure is sufficient to collapse a rectangular varnish can. In a clean can place a few tablespoons of water and bring it to a boil to expel the air with the water vapor. Close the cap tightly as soon as water boils vigorously. Cool the can by dashing cold water on it. ... two comments: You don't need to run cold water over the can. Be sure to

stopper it very soon after you remove the source of heat. If you don't, the reverse effect happens.

19P. DENSITY OF ICE.

Some properties of water make interesting conversation pieces. Demonstrate that ice is lighter than water by placing large icicle in milk bottle (ice cubes may be used). Add cold water to fill jar while holding ice under the water. Let ice float and observe how much water overflows as the ice melts.

20P. DIMPLES AND PIMPLES.

Heat a spot on a cold light bulb with a blow torch and a dimple will form in the glass. Light the bulb and again heat a spot until a pimple forms.

21P. DRY WATER.

Let the student explain why one can pick a coin from the bottom of a beaker of water which has been dusted with lycopodium powder and not wet a finger.

22P. EFFECT OF GAS DENSITY ON SOUND.

Fill several balloons with different gases such as air, carbon dioxide, natural gas, helium, and propane to about the same pressure. Fix a whistle to be blown to a short piece of glass tubing. Note the pitch as gas from the different balloons blows the whistle.

23P. ELEMENTARY BATTERY.

Show emf produced between solutions of different concentrations by using two copper discs attached to insulated wire and suspended in a dilute copper sulfate solution, then drop a few crystals of copper sulfate in to make the bottom layer more concentrated. Connect the electrodes to a sensitive milliammeter or galvanometer.

24P. ENERGY CONSERVATION.

Suspend a bowling ball with a strong cord from the ceiling, Draw the ball back against your nose, with your head against the wall. Release it and stand nonchalantly awaiting its return. It cannot rise to greater than height from which it started.You are save if you do not move or push the ball during its release.

25P. FISSION BUBBLE.

Activation of nucleus to fission may be demonstrated by catching a soap bubble between two wire rings with handles. When caught, puncture the top and bottom areas leaving a cylinder between the rings. Carefully pull the rings apart, noticing the shape of the film, until it breaks in two films over each circle.

26P. FLAME DISCHARGE.

Ionization in a flame can be shown by holding a lighted match near a charged electroscope. Charged pith balls or balloons lose their charge rapidly when a flame is brought near.

27P. GAMES

Games can make both learning and instruction a pleasure. Build puzzle of jumbled letters for other students to solve. An example:

CTVREO	-- has magnitude and direction
DSEPE	-- magnitude portion of velocity
OHNTPO	-- elementary light wave

28P. GROWING SILVER CRYSTALS.

Place a copper penny on the glass slide of a micro-projector. Put silver nitrate solution around copper and watch silver crystals form on screen. Note many peculiar characteristics they exhibit.

29P. GYRO ASSEMBLY.

Weld bicycle axle nuts in end of iron pipes. Screw the pipes on wheel axle for handles. This makes an excellent gyroscope; better when the rim is weighted by winding it with iron wire.

30P. GYRO BAT CIRCLES.

Turn around by swinging baseball bat in circles over head. Reversal of swing reverses motion of body. (Standing on rotating platform.)

31P. GYRO HOME RUN SWING.

Show action and reaction by standing on rotating platform and swinging a baseball bat vigorously at a pitched ball. .... This should be amusing- Do it outside, of course.

32P. GYRO MOMENTS.

Again on the rotating platform, pirouette. Hold heavy weights at arm's length, have someone rotate you slowly. Bring weights close to body. Explain the marked increase in speed.

33P. GYRO PLATFORM.

Construct a rotating platform from an automobile front-wheel and spindle. Rigidness, coupled with small friction and small play in the bearings is amazing. This is useful to demonstrate rotational inertia and maneuvering in space.

34P. GYRO PRECESSION.

Holding gyro axis horizontal, Stand on a rotating platform holding a spinning gyro wheel with its axis horizontal. Observe what happens when the axis is rotated to a perpendicular position to the right? to the left?

35P. HAIR RADIO TRANSMITTER.

Combing the hair near the aerial of a radio produces static.

36P. HEAT TREATMENT.

The effect of heat treatment and tempering of metals can be demonstrated by heating bobby pins to redness in a Bunsen flame. Dip one heated pin in cold water to chill. Allow the other pin to cool slowly. Compare these pins with one that has not been heated by bending each one.

37P. HOLY WATER.

Can molecules of water have spaces between them. Pour water into long test tube or graduate until it is three-fourths full. Then completely fill it to capacity with alcohol. Place your palm over the top of the container and invert it. Be careful that no liquid is lost as the water and alcohol mix. Observe that the container is no longer full. Evidently some alcohol has disappeared in water molecule holes.

38P. HOT DOG WHISTLE.

Tune two metal dog whistles to unison or absence of beats. Heat one whistle with flame. Beats reappear as pitch of heated whistle rises. (Please don't burn your lips!)

39P. HOT ROD BALANCE.

Drill a brass rod for a screw in one end. Insert screw about half way. Balance rod at its center on a pivot. Throw off balance by moving small screw on one end. Heat on end of rod and it will come to balance again.

40P. HYDROSTATIC SCALE.

Weigh yourself by hydrostatic pressure. Use a hot water bottle with a stopper fitted with about two meters of rubber and glass tubing. Fill the bottle with water and connect the tubing so that it extends vertically. Lay the bottle on the floor and cover most of it with a small board of known area. Stand on the board and measure the increased height of the water in the tube. Your weight is equal to the area of the board times the water pressure increase. Calculate the water pressure by multiplying the density of water (1 gram per cubic centimeter) by the difference in the water level height when you stand on the scale.

41P. IMPULSE AND INERTIA MAGIC.

Done with a lot of flourish, this brings down the house! The mechanics of friction, forces and inertia involved make interesting conversation. Set a glass two-thirds full of water about three inches from the edge of a table. On the glass place a pie tin. On the pie tin and directly over the glass place a spool on end. Place an egg (fresh if you are confident) on the spool. With one foot on the bristles of a springy broom, pull back the handle and aim at the pie tin. The spool rolls on the table, the pie tin scoots to the floor, the glass and the water remain unmoved on the table with the egg unharmed in the water.

42P. LENZ'S LAW.

Lenz's Law may be demonstrated with any toy wheel of nonmagnetic material and low friction attached to a convenient holder. Wheel should have spokes for clearest understanding. Spin wheel in air then between poles of a reasonably strong horseshoe magnet. Spokes cut lines of force, induced current field opposes motion.

43P. LOCATING THE CENTER OF GRAVITY.
Start with your hands outstretched and palms facing each other about a meter apart. Rest a horizontal stick or metal pipe on the index fingers of each hand. With your eyes blindfolded, slowly move your hands together until the palms meet. Regardless of the starting position of your hands, the center of gravity of the stick or pipe will be at the point where your hands come together.

44P. MAGNETIC WAVES.

Suspend a bar magnet on a string. Rotate another magnet under it to show transfer of magnetic energy. What changes the direction of the poles? How can the change be effected without human movement.

45P. MASS SPECTROGRAPH.

Properties of alpha, beta, and gamma rays may be demonstrated by propping a smooth board of about eight inches by twelve inches on an incline and arranging a bin with a trap gate at the top so that three different sized balls can be released to roll down the board. Place a strong magnet below the board and just to one side of the gate. Note how each falling ball goes into a separate bin because of the amount of deflection. The gamma may be represented by a brass or aluminum ball, he beta would be the smaller of the steel balls.

46P. MATCH DISCHARGE.

Rubber bands or strips can be tied together in bundles and charged by stroking with fur or by other means. A lighted match near the repelling strands will cause them to collapse.

47P. MATCH HEAD DIVER.

A Cartesian diver can be made with a Coca-Cola bottle full of water and a match head. Keep breaking off the match stick until the head barely floats. Thumb pressure on the mouth of the bottle makes these little divers zip up and down in the bottle.

48P. NEON SINE.

Swing a large 115 volt neon bulb rapidly to show sine curve in space as alternate deltas glow.

49P. NUT DRO

Fix six or seven metal nuts on a string at distances in proportion to 1/2 gt^2 where the time is 1, 2, 3, 4, etc. seconds. Hold string vertical and still and let drop. Note there is no difference in the time intervals as nuts strike the floor.

50P. PAPER KETTLE.

Boil water in a paper cup. The paper will not burn until the water has boiled away.

51P. PAPER WEIGHT.

Cover a wooden slat with a sheet of newspaper except for a few inches which project beyond the edge of a table. Hit the protruding part of the slat with a sharp downward blow of a hammer. The slat breaks without tearing the paper.

52P. PENCIL POINT BALANCE.

To demonstrate center of gravity outside of a body and the criterion for stability, borrow two pocket knives from students. Push blades firmly (but carefully) into a pencil near the sharpened end with the handles beyond the point of the pencil. Balance the pencil point on your finger. Since the system center of gravity falls below the point of balance, the system is stable.

53P. PINHOLE EFFECTS.

An interesting conversation piece can be made from an empty 35 mm film can. In the center of one end punch one hole with a sharp needle. About the center of the other end punch three pinholes at the corners of an equilateral triangle about two millimeters apart. Look through the one hole and see the three holes. Look through the other end at the one hole and explain what is seen. Label the box "Drunk-O-Meter" and list the following directions: 1 hole-sober, 2 holes-nipping, 3 holes-dog drunk, 4 holes or no holes at all -dead drunk.

54P. POURING AIR.

Submerge a beaker full of water in a large water filled container or fish tank. Invert the beaker so its open end is down. Invert a second beaker and submerge it so that air is trapped inside. Pour air from one beaker into another, pouring up. Note fluid nature of the gas.

55P. POURING CARBON DIOXIDE.

Construct a series three 5-cm steps that will fit into a wide mouth jar. Set a lighted candle on each step. Slowly pour carbon dioxide gas from an open container into the jar. Carbon dioxide is heavier than air. As it settles it extinguishes the candles one by one starting with the candle at the lowest level. There are many ways to generate carbon dioxide. Try mixing some vinegar with bicarbonate of soda.

56P. PRECISION IN ADVERTISING.

Encourage students to think, speak, and write more precisely. Illustrate by using a meaningless advertising slogan: "The Rolls-mobile is bigger and better: -than-

(a) a diddie car
(b) a freight car
(c) last year's model.

57P. RATE OF HEAT CONDUCTION.

Three students each holding a rod of a different substance in a flame, will demonstrate the difference in conductivity of heat by their object from the flame. Use about the same sized rods of iron, aluminum, glass, copper.

58P. REACTION OF THE ROAD.

Place plank on rollers (doweling). With string, tie a small cart to one end of the plank and stretch a long rubber band between the cart and the other end of the plank. Add weights to the cart to increase its mass. Burn the string to release the system. The road goes one way, the cart goes another.

59P. RETINAL AFTER EFFECTS.

Draw a circle in the center of a piece of white paper with colored crayon. Stare at the circle at arms length for a time, then look at a blank wall. A circle of some other color appears on the wall.

60P. ROLLING SPOOL.

Select a large spool and wrap several turns of ribbon or twine around it. Place the spool on a table so it can roll when the free end of the ribbon is pulled out from the spool bottom. Observe the direction that the spool rolls when the ribbon is pulled straight up and when it is pulled at other angles closer to the horizontal. With a little practice, the spool can be made to roll in either direction as the ribbon angle is changed. Encourage students to explain the phenomena using terms such as torque, friction, and vector direction of force.

61P. SEEING THE SUN BEFORE SUNRISE.

Evidence that one may see the sun while it is still below the horizon can be visualized by looking at a penny at the bottom of a bowl filled with water. Note that the penny cannot be seen over the rim of the bowl unless there is water in the bowl. When the sun first appears in the morning, it is still our of sight below the horizon. Refraction of the sunlight by the atmosphere makes the sun appear higher than it really is.

62P. SELECTIVE IMAGE INVERSION.

Print with capital letters the word TITANIUM DIOXIDE. Use a red pencil for the first word and a blue pencil for the second. View both words through the side of a test tube filled with water. Only the red word looks inverted.

63P. SELECTIVE LIGHT SCATTERING.

Demonstrate the effect of the sun setting through the dust-laden atmosphere. Add five grams of sodium thiosulfate and 5 mL of concentrated hydrochloric acid to a liter of water in a clear container. Shine a light through the solution and on to a wall or screen. Observe the changes as the colloidal sulfur forms. Scattered blue light can be seen in the solution at a ninety degree angle from the beam. On the screen or wall the spot slowly changes from white to yellow, to red, and then is finally is blacked out completely.

64P. SHADOW REFRACTION.

Place an object on the bottom of a metal pan so that its shadow may be measured. Fill the pan with water and remeasure shadow. Refraction is evident if pan, object, and light source are kept stationary.

65P. SINGING FLAME VARIATION.

Hold a four foot 1-1/2 inch glass tube vertical. Insert in the bottom end at a predetermined resonance point a heavy disc of wire gauze. Heat the wire gauze with burner, then remove flame and hear a phenomenon.

66P. SINGING TUBES.

A straight metal blow pipe connected to a gas supply is fixed in an upright position on the demonstration desk and lighted. A thirty to sixty centimeter glass tube of large diameter is lowered over the flame until at a certain position a sound is heard.

67P. SKY HOOK.

Cut a four inch piece of wire from a coat hanger. Bend one half inch back on one end so that a leather belt will slip in the hook. Rest the free end of the wire on a finger tip. The belt and wire will hang out in space without apparent support underneath.

68P. SPINNING HAMMER.

Mark the center of gravity of a hammer with a spot of paint. Toss the hammer into the air with a spin and note that the spot is the most stationary point of the hammer as it spins.

69P. STANDING WAVES ON A STRING.

Wave motion and standing waves can be demonstrated by attaching a vertical string to almost any small electric motor or vibrator. An electric shaver is ideal. Hang weights of varying amounts on the string. As the tension increases, there will be changes in the length of the standing waves.

70P. UNLIMITED WATER SUPPLY.

Suspend a water faucet above a sink by a thin wire. Water can be made to flow continuously in a strong stream from the faucet bottom despite the fact that the faucet is not connected to any water pipes. The secret is to use a concealed electric water pump that pushes water up a glass tube into the bottom of the faucet. As the water emerges, it flows over the outside of the glass tube concealing the tube from view. This makes an interesting corridor display.

71P. STEREOSCOPIC VISION.

Look through a paper tube at some distant object with the right eye while holding a book over the other eye and close to the tube. It will appear that one is looking through a hole in the book.

72P. STRETCH CHARGE.

Stretch a rubber band tightly and rub against an electroscope. Determine the nature of charge produced.

73P. SUSPENDING SOAP BUBBLES.

Show that a soap bubble filled with air will float on carbon dioxide. Using a bubble pipe or straw, blow a soap bubble and carefully place it in the center of a jar partially filled with carbon dioxide. Because the carbon dioxide is invisible the bubble appears to be suspended without any support.

74P. SWINGING PENDULUM.

Show conservation of energy in a swinging pendulum by noting that it returns to the same level each time. Place an obstruction below the point of rotation so that the arc of swing will be changed. Change the obstruction to a point one half the distance between the lowest and highest levels and again below this point. Explain why the bob loops over the obstruction.

75P. THUNDER BUBBLES.

Prepare a soap bubble solution in a shallow dish or pan. Fill a balloon or beach ball with a 2 to 1 mixture of hydrogen and oxygen. Using a small nozzle delivery tube, blow the gas mixture from the balloon through the soap solution to produce copious bubbles. Pick up handful of bubbles and hold them far out in front of you. Ignite the bubbles with a match. The explosion will not be felt by you. However, someone standing too close to the bubbles may have an ear injured. .... sound is indeed intense. Try this in a long hall and get good reverberations.

76P. THUNDERING GRADUATE.

Suspend a coiled platinum wire just below the lip and inside an English graduate containing a few milliliters of ammonium hydroxide (concentrated). Bubble oxygen through the ammonium hydroxide. Violent explosions occur. ... I don't even know what an English graduate is!

77P. TUBELESS TELEVISION.

Prepare a slide with a few simple words such as THAT'S ALL cut in a piece of metal foil. Aim the slide projector so the beam goes out an open door and does not attract attention. In a darkened room, wave a white wand in the plane where the image is focused. Persistence of vision creates a complete image, apparently materializing the words in space.

78P. VARIABLE DENSITY.

Moth balls rolled in sodium bicarbonate and put into a cylinder of very dilute hydrochloric acid will rise and fall with regularity.

79P. VARIABLE VOLUME SPONGE.

A dry plastic sponge can be measured for volume. Ask how much water you can pick up with it. When wet, it may pick up more than its initial volume. It expands slightly and is mostly a "lot of air holes fastened together."

80P. VISCOSITY REACTIONS.

Let a few students with egg beaters beat oils of different viscosity. Those having to beat the heaviest oils will tire first.

81P. VISUALIZED WORK UNITS.

Mount a 12 inch length of 2x2 inch wood upright on a base. Mount another one slightly over 9 inches long on the same base. Lifting a one-pound weight from the base to the top of the one foot tower represents one foot-pound of work. Lifting the weight to the top of the 0.76 foot tower represents one joule of work. A feather lifted from the table top on to a piece of paper laying on the table represents an erg of work. A millionth of a millionth of an erg is called an electron-volt.

82P. WATER GLASS SUCKER.

Carry a glass brim full of water up a ladder and press it to the ceiling. Ask the "sucker" to push against the bottom of the glass with a long pole while you climb down and put away the ladder and go on about other business. If the ceiling is smooth, the student need not fear that the glass will fall.

83P. WHISTLE BEATS.

Prepare two small whistles with a screw in the end so that the length of the air column can be adjusted for different frequencies. Attach the whistles to a Y tube so that they can be blown simultaneously. When the pitch of one is slightly different than the other, a low pitch "beat note" is heard.

84P. WOOD'S METAL.

Carve a spoon mold in wood and fill with molten Wood's metal. The spoon will melt in hot water, coffee, or tea. Save the mold to recast the spoon as part of the demonstration.

96 Demonstrations on the borderline between physics and chemistry

1PC.

A glowing picture can be made out of this "invisible ink". Mix 40 grams of potassium nitrate and 20 grams of gum arabic in 40 ml of water. You can use an old writing pen or brush to draw your picture or message being sure that all lines connect. If you trail a line over to the edge of the paper and let this dry, you can hold a match to this spot and watch the ink start to glow and scorch the paper under it. Hopefully your art won't all go up in flames.

2PC.

Interesting crystal patterns can be shown by dissolving a small quantity of dextrin (gum arabic and tragacanth are not so suitable) in an aqueous salt solution as concentrated as possible, for instance, in magnesium sulfate, or zinc sulfate or other salt. Filter the solution and coat glass plates evenly with the filtrate. Leave them lying horizontally until the water evaporates. The crystals should be difficult to remove and are very intricate, like frost.

3PC.

Here is a recipe for that "old time" flashpowder for photography. 6 grams powdered magnesium, 12 grams potassium chlorate. Mix lightly with a wooden spatula with care. You can ignite the powder by applying flame or placing it on wax paper and lighting the paper. Only use about 1 gram of this powder and it is best to only make as much as you will immediately use. It's not safe to store.

4PC.

Here is another recipe for flashpowder. Take the same precautions as stated above. 4 grams powdered aluminum, 10 grams potassium chlorate, 1 gram sugar. All these powders are smokey, but some smoke may be trapped by hanging a wet towel over the powder to catch the smoke cloud.

5PC.

You can make Wood's metal by melting 2 parts tin, 4 parts lead and 5 to 8 parts bismuth. It will melt around 151 to 162 degrees F. Another recipe calls for 7 to 8 parts bismuth, 4 parts lead, 2 parts tin and 1 to 2 parts cadmium. This will melt at around 158 degrees.

6PC.

Paper chromatography can be quickly demonstrated by placing a spot of most any ink near one end of a strip of filter paper which touches water.

7PC.

A hot water bottle that demonstrates heat generated by the heat of fusion can be made as follows: mix sodium acetate and sodium hyposulfate in the proportion of 1 part acetate to 9 parts hyposulfate and fill a bottle or beaker about 2/3 full of the mixture and place it in hot water or in the oven until the salts melt. Be sure to seal the bottle as well. The bottle will radiate heat for at least a half a day or until all the salt solidifies. Shaking the bottle will renew its heat-giving properties.

8PC.

To make aspirin, prepare a water bath by heating a 400 ml beaker about 2/3 full of water and bring it to a boil. To a conical flask add 6.00 g. of salicylic acid and add about 8 ml of acetic acid. Swirl and place in beaker of boiling water for about 15 minutes or until solid dissolves. Remove from boiling water and cool under running tap water. Add about 25 ml of ice water and set flask in ice bath until crystallization appears complete. Filter crystals from liquid. Purify crystals by dissolving in 20 ml of ethanol in a 100 ml beaker. Warm if crystals do not dissolve completely in a warm water bath.. Next add 50 ml of warm water to solution and set

in ice bath to speed cooling. Filter out the aspirin crystals. 100% yield should give 7.82 grams of aspirin.

9PC.

Equip a flask filled with water with a two-hole stopper having a glass tube reaching the bottom of the flask and drawn to a nozzle at the other end in one of the holes; in the other hole place a long glass tube with a thin bulb filled with ether on its submerged end. Seal the top of the ether tube. When the bulb is broken inside the flask, the ether vapor will force the water from the nozzle.

10PC.

To make methyl salicylate (oil of wintergreen), put about 1 gram of salicylic acid on an evaporating dish and add to it 1 ml of methanol. Next, add 3 drops of concentrated sulfuric acid and warm gently. You should be able to identify the odor.

11PC.

Cotton or filter paper saturated with turpentine and put into a quart fruit jar or wide mouth bottle of chlorine gas will spontaneously react. Have jar cover handy to prevent soot from covering the room.

12PC.

In digging through Henley's formulas, I found this formula for gunpowder. 75 grams potassium nitrate, 15 grams charcoal, 10 grams sulfer. You might mention that gunpowder is not an explosive unless it is under pressure. Gunpowder won't even burn in a vacuum if ignited with a red hot platinum wire.

13PC.

Some brave soul may want to try this. Get a beaker of ethanol- a good source might be Everclear, not denatured, and ignite it. You can dip a banana into the burning alcohol and eat it as it burns. The fire will go out in your mouth.

14PC.

Scrape clean two one-by three inch strips of lead and submerge them in a 5 N solution of sulfuric acid. Charge the cell by connecting the strips to a three volt battery for a couple of minutes. Discharge by connecting the cell to a bell or light bulb.

15PC.

A copper strip or wire suspended in a silver nitrate solution produces a silver tree by the replacement action.

16PC.

When explaining conductivity, ionization, and their relation, remember that hydrogen chloride (HCl) does not show ionization in benzene, nor does it conduct an electric current. In water, HCl becomes an excellent conductor. Glass does not conduct electricity except when hot, plastic, or molten. Try it with 115 volt conductivity apparatus.

17PC.

Most solids are more soluble in hot water that in cold water. Calcium acetate is a common exception to the above, showing negative solubility , and is precipitated out when its water solution is heated.

18PC.

Antimony trichloride is not soluble in water but will dissolve when chloride ion concentration is increased by adding concentrated hydrochloric acid. Diluting the solution with water precipitates antimony oxychloride and again concentrated hydrochloric acid will put it back in solution.

19PC.

Chemical reaction between gases under water can be shown by bubbling acetylene gas and chlorine gas into water in such a manner that the bubbles come in contact before they surface. As a suggestion for better viewing in the reaction, fit a glass tube with a two-hole stopper to make the apparatus.

20PC.

The difference in degree of solubility of a solid in various liquids can be demonstrated by carefully pouring carbon tetrachloride, water, and ether into a cylinder to layer them. A few crystals of iodine dropped through the layers will dissolve as they fall through the different layers. The degree of color in the liquids will indicate the amounts dissolved.

21PC.

Solubility of ammonia gas is quickly demonstrated by putting five mL. of ammonium hydroxide in a 500 mL flask equipped with a one-hole stopper, glass tubing drawn to a nozzle on one end and attached to a long heavy rubber tubing. Heat the flask and ammonium hydroxide until ammonia gas comes from the open end of the tube. Place tube end in water and await action.

22PC.

When it is desired to collect the hydrogen displaced from water by sodium metal, it is sometimes difficult to get the metal under water and into the container without unwanted incident. The sodium metal can be pinched closed with tweezers and inserted in the collecting container where it will surface without carrying air.

23PC.

Spontaneous ignition results when glycerin is dropped on a small heap of potassium permanganate. Magnesium powder along the edge adds to the spectacle. (protect desk top from splattered particles) .... worked for us only with $KMnO_4$ ground in a mortar with pestle.

24PC.

Combustibility of certain dust particles in air can be vividly demonstrated by placing corn starch in a handkerchief or cloth bag and dusting through the cloth mesh into a flame. .... or put some powder in the end of a piece of glass tubing and blow this into the flame. Messy!

25PC.

Sometimes there are times you wish to etch glass. Other than using sandblasting, you may use hydrofluoric acid, but this is nasty stuff to keep around. Dissolve about 72 grams of sodium fluoride and 14 grams potassium sulfate in water for one solution and 28 grams of zinc chloride and about 130 ml. of hydrochloric acid in 130 ml of water for the second solution. Mix only a small amount of these solutions together and use a brush or pin to paint the glass. It will generate hydrofluoric acid and should etch the glass in about half an hour.

26PC.

Catalytic oxidation of methyl alcohol can readily be accomplished by suspending a heated coil of platinum wire in a partly covered beaker of methyl alcohol. The product is recognizable to biology students as formaldehyde.

27PC.

Prepare a tincture of iodine and potassium iodide. Place a drop on a microscope slide and project on a screen with a microprojector. The heat from the lamp will produce beautiful color and crystallization effect.

28PC.

Collect ammonia over mercury. Allow a single drop of water or $CuSO_4$ to rise through the mercury to the gas. Explain the absorption of the gas in each.

29PC.

Use $K_2Cr_2O_7$ as a catalyst in $KClO_3$ instead of the usual MnO_2. Less is required.

30PC.

When copper and cobalt ions are used to harden water, the ion exchange area is visible in a zeolite column. Copper and cobalt are analogous to magnesium and calcium in most natural hard water.

31PC.

Student feels heat of hydration when a small amount of anhydrous copper sulfate is placed on hand and a drop of water is added to it. The heat involved is large. Have water ready to cool off the hand.

32PC.

Place equal amounts of calcium carbonate solution into two cylinders. Buffer one cylinder with a sodium acetate solution before putting equal amounts of two normal (2N) acetic acid into each. Explain the difference in the rate of reaction.

33PC.

The solubility of calcium butyrate decreases with increasing temperature, unlike most compounds.

34PC.

There are many invisible inks. Write with solutions of the following chemicals and develop as indicated: AgNO3 - light; CoCl2 - Pb(C2H2O2) - H2S; Co(NO3)2 - oxalic acid; Starch - iodine; CuSO4 - NH3.

35PC.

Bubble CH4 through a solution of H3BO3 in CH3OH in a flask fitted with a two hole stopper. Insert a Y-tube in the other hole of the stopper and attach to one arm a Bunsen burner. To the other arm attach a drying tube filled with activated charcoal, then to a bunsen burner. Light both burners and explain the difference in flame color.

36PC.

Place a slug of pure Zn in dilute H2SO4 and note that polarization prevents the continuing of hydrogen evolving. Attach a small platinum wire to the slug and again place in acid. The zinc will now be completely consumed. Why do the bubbles come off the platinum?

37PC.

Cover the bottoms of two beakers with gasoline in one and kerosene in the other. With asbestos squares for covers to beakers handy, pitch lighted match into the gasoline. Smother flame with asbestos square and repeat procedure with beaker of kerosene. Heat kerosene and try again. Do not heat the gasoline!

38PC.

Alcohol, carefully floated on concentrated sulfuric acid in a test tube exhibits flecks of fire at the interface when potassium permanganate crystals are allowed to fall through the liquids. .... this also is spectacular , particularly with small groups of students. Write the equation.

39PC.

Natural acid-base indicators can be had in such common foods as blue-berry juice, red cabbage, carrot, beet, etc. Determine over what range of pH they operate.

40PC.

Put equal quantities of water in two small beakers. To each add one of the following chemicals in equal amounts. Barium oxide is exothermic while ammonium nitrate is endothermic. Pass the beakers around for inspection.

41PC.

Wash freshly cut lead shavings with distilled water. Pour the water through a resin ion exchanger and develop by the usual methods.

42PC.

Lead ions combined with iodide ions produce plumbous iodide which, when washed and recrystallized from hot water, produce interesting
golden crystals.

43PC.

Magnesium burns in water! Prepare a test tube by blowing a small hole near the bottom. About one inch up the tube from its center place a coil of magnesium ribbon. Fill the test tube about half full of water, stopper and invert so that the water does not touch ribbon. Heat top layer of water to boiling; then heat water and ribbon rapidly until ribbon ignites. Ignite hydrogen gas as it comes out of the hole in the test tube.

44PC.

Copper sulfate solution poured over Dowex 50X resin loses its color through ion exchange. Sodium chloride solution poured over the above resin removes the copper sulfate and the effluent is again colored.

45PC.

A relatively cold flame may be produced by igniting a mixture of carbon tetrachloride and carbon disulfide (or watered alcohol). On preparing the mixture, first prepare a mixture with too much carbon tetrachloride (or water) so that the mixture will not ignite. Add a small quantity of carbon disulfide to a portion of the mixture and test it for the right temperature. A handkerchief may be dipped in the mixture and held in the hands while burning if it is kept moving.

46PC.

A coiled platinum wire suspended from a rubber stopper in a flask filled with ammonia gas and air will glow for about ten minutes. Blow over the mouth of flask to replenish oxygen. .... Use conc'd NH3 solution with the top open to the air.

47PC.

Catalytic oxidation of ammonium hydroxide is spectacular. Suspend a coiled platinum wire in an English graduate just above the surface of some ammonium hydroxide. Bubble a fine jet of oxygen through the ammonium hydroxide. Violent explosions! ... not for the faint of heart. .... I like a small coil of Pt wire above conc'd NH3 in a small Erlenmeyer. Glows for hours.

48PC.

Dissolve a few crystals of cobalt chloride and potassium thiocyanate in a graduate one-third full of ether. Add and equal volume of water to separate red and blue colors. A few drops of silver nitrate solution in the mixture completes the patriotic colors.

49PC.

Interesting intermittent explosions and flame travel can be demonstrated by placing a four-foot by one and one-fourth inch glass tube in a vertical position with a lighted burner at the top and a source of methane gas induced at the bottom.

50PC.

Fill a Coca-Cola bottle with two parts hydrogen gas to one part oxygen. Stopper and wrap bottle with cloth or tape. Hold bottle bottom against chest and bring lighted match to mouth of bottle while removing cork. The sonic boom is in the order of 3-5 electron volts - had it been a nuclear reaction, instead of chemical, the explosion would have been on the order of 212 Mev. and much louder. .... take care with this one, possibility of flying glass!

51PC.

Zinc powder mixed with ammonium nitrate will produce voluminous white smoke when ignited at arms length with a Bunsen burner.

52PC.

Show how coal may be separated from shale through flotation. Prepare a zinc chloride solution in which coal will float and shale will sink.

53 PC.

Show samples of chemicals as they are discussed in class. Some of the chemical and physical properties of substances may be shown by heating the materials separately and combined in test tubes. Try iodine and sulfur.

54PC.

Prepare oxygen several different ways: 1) add yeast to a 3% or 6% percent solution of hydrogen peroxide 2) add manganese dioxide to hydrogen peroxide 3) Heat sodium nitrate 4) Add sodium peroxide to water.

55PC.

The stabilizing action of colloids is a principle utilized in the "Foamite" fire extinguisher. Into each of two tall cylinders or hydrometer jars pour a solution of sodium bicarbonate. Add a teaspoon of licorice extract to one. Add aluminum sulfate solution to each and notice how carbon dioxide bubbles subside rapidly in one while foam rises over the top of the other container and spreads.

56PC.

Mix two parts hydrogen or natural gas with one part of oxygen into a syrup can equipped with a spark plug. Use a high frequency coil to furnish the spark which will cause combustion and combine the gases.

57PC.

Match sticks are chemically treated except for the tip where machines hold them. Burn a match completely. Observe the difference between the ash or char left from the treated and untreated regions.

58PC.

Mix (don't grind) one part sugar with three parts potassium chlorate. Incorporate Na, Ba, Ca, Sr, Cu, and BO3 ions with portions of the mixture on a long trough. Light one end and observe the different colors which appear in the flame.

59PC.

Hold a match head in a Bunsen flame in such a way that the stick burns but the head does not ignite. This is evidence that some parts of the flame are cool.

60PC.

Cup hands over an unlighted Bunsen burner to collect gas. Ignite this gas at a lighted burner and carry the flame back to ignite the gas of the first burner to show that flame results from a burning gas. One of our people tried this without burning himself... but the demonstration didn't work as described.

61PC.

Mercuric thiocyanate made into a small cone by the aid of dextrin forms a pharaohs serpent when burned. Such items always create interest ... but avoid breathing the vapor which contains poisonous mercury compounds.

62PC.

To demonstrate how water aids chemical reaction, add about a gram of potassium bitartrate to an equal amount of sodium bicarbonate to a test tube. Shake and note no reaction. (Explain that these are the essentials of cream of tartar baking powder which may keep for months on the grocer's shelf) Add a little water and the effect is evident. Ions are more active than atoms or molecules and water probably acts as a catalyst or at least promotes ionization.

63PC.

Relative vapor pressures of liquids can readily be shown. Attach manometer tubes to three bell jars of same size. Fill tubes with colored light liquids. Place the bell jars over dishes containing water, alcohol, and ether all at the same temperature. Dishes and bell jars may need to be set on glass plates to obtain air tight seals.

64PC.

Allow students to check the pH of their own saliva by using Hydrion paper. The color chart (usually on the Hydrion vial) will indicate quite a range of pH through the class.

65PC.

Investigate the structure of a Bunsen flame by adjusting it to a height of 5 cm or more. Holding a splint in the flame horizontally at various levels. Heat intensity for each level is indicated by the degree of scorch on the splint. This may be varied by inserting a vertical card in the flame and tilting it slightly. A scorch pattern will appear showing heat intensities of various areas of the flame. Also, a wire gauze held in the flame will show by its glow the same conditions. Probe the flame with a small thermocouple connected to a sensitive ammeter and interpret the meter readings.

66PC.

Demonstrate spontaneous ignition by placing a half teaspoon of sodium peroxide on a two-inch cone of starch, sawdust, or finely chopped paper. Lay a small chip of ice on the cone. Heat and oxygen is released when water from the ice reacts with the sodium peroxide. Kindling temperature and oxidation may be discussed following the demonstration.

67PC.

A dust explosion may be made from a syrup bucket or any can with a tightly fitting friction lid. Punch a hole in the bottom large enough to admit the small end of a funnel. Attach a length of rubber tubing to the extended funnel. Place a single thickness of Kleenex in the funnel to support a teaspoon of lycopodium powder. Place a six-inch lighted candle on the opposite side of the can from the funnel. Close the lid firmly and give a quick puff on the rubber tube. The lid usually hits the ceiling.

68PC.

Pass cut strips of cobalt chloride paper directly from the desiccator to some or all of the students. Have them hold paper tightly in the palm of their hand for a minute. They will note a change of color. Various explanations will ensue.

69PC.

Pour copper sulfate solution over coarse iron filings on a filter paper. The blue solution on coming through the filter will be colorless. If a small amount of acid was placed in the

collecting container, when the solution is poured back through the filter, it will again be colored.

70PC.

Mix a little concentrated sulfuric acid (CARE!) and potassium permanganate in an evaporating dish. Dip a glass rod into the mixture and immediately touch the rod with attached mixture to the wick of an alcohol lamp. The alcohol ignites.

71PC.

For a quick demonstration of colored flame, ion color, or burning of metal, keep salt shakers filled with powdered metals such as iron, aluminum, magnesium, zinc, and antimony. Dust these into a bunsen flame. Salts of strontium, lithium, barium, copper, and sodium can be sprinkled into a flame by the same method.

72PC.

One demonstration seldom offers so many illustrations as does "Barking Dogs," yet remains so simple to perform. Dissolve a small amount of white phosphorus in carbon disulfide. CAREFUL! FLAMMABLE! A few drops of this solution on filter papers placed on top of a number of empty glass cylinders of varying capacities will illustrate :

73PC.

Dramatization of valence in simple reactions can be shown by two girls holding the other's hands (representing oxygen molecules) and four boys, each with one hand in his pocket but holding another boy's hand (representing hydrogen molecules.) The three molecules represented will break apart at the introduction of a suitable catalyst (represented by a popular dance tune) to form H-O-H.

74PC.

The amphoteric nature of aluminum can be demonstrated by reacting aluminum sulfate with sodium hydroxide to obtain aluminum hydroxide precipitate. Treat the aluminum hydroxide precipitate with more sodium hydroxide and get sodium aluminate and water. These last products treated with hydrochloric acid precipitate aluminum hydroxide. This precipitate treated with more hydrochloric acid yields aluminum chloride and water.

75PC.

The green flame characteristics of borax can be shown by burning alcohol to which a little sulfuric acid and borax have been added.

76PC.

Five milliliters of calcium acetate poured into forty-five milliliters of ethyl alcohol will form a false gel that resembles canned heat.

77PC.

Iodine crystals added to ammonium hydroxide form nitrogen triiodide. These crystals are extremely sensitive when dry and will explode on being touched delicately with a feather.

78PC.

Light gases diffuse downward. Fill a wide mouth bottle with hydrogen. Invert over a like bottle filled with air. While waiting for the diffusion to take place, be democratic and allow the class to predict the result. Suggest possibilities such as: (a) the hydrogen being lighter will remain in the top bottle, (b) the gases will mix together, (c) all the hydrogen will go to the bottom bottle. At the end of about five minutes, test each bottle with a burning splint. Elicit the moral that democracy works best when voters are educated with sufficient facts and information.

79C.

Heat strongly some protein in a test tube having pieces of litmus paper and lead acetate paper over the lip. Blackening of protein shows its carbon content; litmus turns blue, indicating ammonia; lead acetate paper turns black, indicating the presence of hydrogen sulfide; water condenses on side of the test tube.

80PC.

In a can with a tightly fitting lid, cut a small hole in the side near the bottom and another in center of lid. Fill the can with natural gas. Then ignite the gas as it comes from the hole in the lid. Flame will at first be large and yellow. It gradually changes to blue and may become invisible as air is drawn into the bottom hole and mixed with the gas. When the gas air mixture reaches the proper proportions an explosion will blow the lid off the can.

81PC.

A Halo type shampoo poured on a small amount of manganese dioxide in a graduated cylinder will produce copious lather on addition of a solution of hydrogen peroxide.

82PC.

Aluminum powder mixed with iodine will ignite when a drop of water is added. (care with vapor)

83PC.

Heat of oxidation is evident when a piece of aluminum foil is wrapped around the bulb of a thermometer and the preparation immersed in $HgCl2$ solution.

84PC.

A model of a Bunsen burner made from a three-foot piece of one-inch glass tubing is excellent for class demonstrations of strike-back gas-air mixtures, flame structures, etc. Mount a large glass tube vertically on a stand. Fit the bottom of the tube with a one-hole

stopper equipped with a small glass tube for injection of the gas. Light the burner adjusted for a rich mixture of gas and adjust cork for other effects.

85PC.

A chemical garden can be grown in a solution of 150 mL of water in which 35 mL of sodium silicate has been dissolved. Growth will start when crystals of compounds containing colored ions such as Cu, Co, Ni, Fe, and Al are added to the solution.

86PC.

Show that the wetting property of water is increased with the addition of detergents by filling two cylinders with water, one having a detergent added. Place a piece of wool yarn, or non-absorbent cotton ("ducks") , on each surface and observe the time required for the wool to sink.

87PC.

Produce the patriotic colors by pouring sodium hydroxide solution into three beakers containing one each of the following solutions; phenolphthalein, lead acetate, and copper sulfate.

88PC.

The gas laws may be illustrated by a device prepared by drilling holes near each end and in the center of a small board about the size of a yardstick. Label each hole appropriately; Pressure, Temperature, and Volume. Show by pivoting at center hole (Temperature) if temperature remains constant and pressure rises, the volume will lower (decrease) etc. Other variations will show different aspects of the laws.

89PC.

Form a paste in a small beaker of para-nitroanaline with concentrated sulfuric acid. Heat this mixture over a Bunsen flame. The reaction produces a long sausage-like plastic mass which is quite spectacular.

90PC.

Show crystallization of a supersaturated solution by by adding sodium thiosulfate to hot water and letting it cool slowly. Then, seed the cooled solution with a speck of the original material. The contents will become practically a solid in a short time. Also try melting sodium acetate in its own water of crystallization by using a double boiler. The resulting supersaturated solution behaves in a spectacular manner.

91PC.

Watch crystals as they grow on a microscope slide. Place some Salol powder (Phenyl Salicylate) on a slide and heat it with a match. The melting point of Salol is only 42-43 degrees celsius. When the liquid has cooled, seed it with a speck of the original material and see the crystals forming.

92PC.

Using a fine nozzle blow pipe prepared from a glass tube, blow small bubbles in a pan of water containing "Tide" or "Joy". The bubbles will arrange themselves in pattern somewhat like molecules as they form crystals.

93PC.

The burning of a wood match shows among other things, destructive distillation, burning of a gas, and burning of a solid at the crimped end after the flame disappears.

94PC.

Gases are held in compressed volume by molecular forces of occlusion. Fill a large mouth bottle with granular activated charcoal. Fit the bottle with a two-hole stopper carrying a thistle tube and delivery tube. Announce that this filled bottle contains more than its volume. Proceed to demonstrate by slowly filling the bottle with water while collecting the gases over water from the delivery tube.

95PC.

Flame analysis can be done without the expensive platinum wire and without the necessary cleaning before each test. Dissolve a small amount of salt to be tested in a few milliliters of alcohol. Ignite the alcohol in a clean dish and notice the color. As a safety precaution use this technique to produce colored flames for your alcohol lamps. Without the salt, alcohol lamp flames are nearly invisible.

96PC.

A burning match head pressed against a silver coin shows direct combustion between sulfur and silver. Also, a hard-boiled egg yolk and silver coin gives the same result. .... the trouble is trying to find a silver coin nowadays.

Resources on Demonstrations

Books

Physics Experiments and Demonstrations: Selected from the American Journal of Physics 1933-1964, a bibliographic guide, Publication R-182, American Institute of Physics, New York, 1965.

A. B. Arons, *A guide to introductory physics teaching*, New York: Wiley 1990

D. Rae Carpenter, Jr. and Richard B. Minnix, *The Dick and Rae Physic Demo Notebook*, Dick and Rae, Inc, Lexington, Virginia 1993.

R. D. Edge, *String and Sticky Tape Experiments*, AAPT 1987

R. Ehrlich, *Turning the World Inside Out and 174 Other Simple Physics Demonstrations*, Princeton University Press, New Jersey 1990, ISBN 0-691-08534-X.

R. Ehrlich, *Why Toast Lands Jelly-Side Down. Zen and the Art of Physics Demonstrations*, Princeton University Press, New Jersey 1997, ISBN 0-691-02887-7.

H. F. Meiners, *Physics Demonstration Experiments*, Roland Press 1970

J. S. Miller, *Demonstrations in Physics*, Ure Smith, Sydney, London, 1969.

R. M. Sutton (ed.), *Demonstration Experiments in Physics*, McGraw-Hill, New York 1938

C. E. Swartz and T. Miner, *Teaching Introductory Physics: A Sourcebook*, AIP 1996

Journals

American Journal of Physics
http://ojps.aip.org/ajp

Computers in Physics (1987 - 1998)
www.aip.org/cip
Some of the articles in Computers in Physics (now transformed into Computing in Science and Engineering) have an educational angle.

Computers in Science and Engineering
http://www.computer.org/cise/
Has an educational column where examples of how computers are used in education are shown.

Journal of Chemical Education

http://jchemed.chem.wisc.edu
Many interesting experiments that can be used in physics.

Journal of Computer Assisted Learning
http://www.blackwell-synergy.com/rd.asp?goto=journal&code=jca

Journal of Physics Teacher Education Online
http://www.phy.ilstu.edu/jptes/

Mercury Magazine
http://www.astrosociety.org/education/publications/articles.html
Astronomy education
Physics Education
http://www.iop.org/EJ/journal/PhysEd
The most recent articles in Physics Education are free for downloading for a period of one month. It is also possible to set up an email alert for new articles.

The Astronomy Education Review
http://aer.noao.edu/
A journal/website that provides a meeting place for all who are engaged in astronomy education.

The Electronic Journal of Science Education
http://unr.edu/homepage/jcannon/ejse/ejse.html

The Journal of Information Technology Education (JITE)
http://www.jite.org/
An annual publication that seeks to "improve IT education around the world by publishing high quality articles on best practices and other topics".

The Online Journal of Undergraduate Research in Physics
http://jurp.org/
A journal where many good ideas can be found for Extended Essays.

The Physics Teacher
http://ojps.aip.org/tpt
The Physics Teacher has for each issue some featured articles that can be freely downloaded.

Resource Letters

E. L. Jossem, *Resource Letter EPGA-1: The Education of Physics Graduate Assistants*, American Journal of Physics **68**, pp. 502-512 (2000).
http://www.physics.ohio-state.edu/~jossem/AJP502.pdf

L. C. McDermott and E.F. Redish, *Resource Letter: PER-1: Physics Education Research*, American Journal of Physics **67** p. 755 (1999).
http://www.phys.washington.edu/groups/peg/rl.htm

WWW Sites

Auburn University Physics Demonstrations
http://www.physics.auburn.edu/demo/demo.html

Clemson University Physics Lecture Demonstrations
http://virtual.clemson.edu/groups/physdemo/main.htm

CMU Physics Demonstrations
http://bednorzmuller87.phys.cmn.edu/demonstrations/

Georgia Tech School of Physics - Demonstration Facility
http://www.physics.gatech.edu/demopage/

U. C. Berkeley Physics Lecture Demonstrations
http://www.mip.berkeley.edu/physics/physics.html

U. C. Riverside Physics Lecture Demonstrations
http://phyld.ucr.edu/default.htm

U. C. Santa Cruz Physics Demonstration On-Line Catalog
http://nemesis.ucsc.edu/

University of Guelph Physics Demonstrations
http://www.physics.uoguelph.ca/Demo/demo.html

University of Maryland Physics Lecture-Demonstration Facility
http://www.physics.umd.edu/deptinfo/facilities/lecdem/index.html

University of Minnesota
http://www.physics.umn.edu/groups/demo/demo_index.html

Part V

Web Physics

Web Physics Assignments with Hot Potatoes

In recent years the (World Wide) Web has been used to create active learning environments in introductory physics teaching. In the Just-in-Time Teaching (JiTT) approach [1,2], the students do a Web-based preparation assignment due by electronic transmission a short time before classes. The assignments might be conceptual multiple choice exercises (and thus share some characteristics of the Peer Instruction method [3,4]) or problems based on online simulations (e. g., physlets – see next section). The choice of classroom activities may then be guided by the total response to these assignments.

For many teachers the amount of investment in time needed to make such assignments from scratch, is too large. The purpose of this note is to show how a free collection of tools called Hot Potatoes [5] makes it very easy to design sophisticated types of online assignments: The generated web pages will automatically grade the responses from the students and send the graded results to your mailbox for review.

Downloading and Installation

The latest version of Hot Potatoes can be downloaded from the URL http://web.uvic.ca/hrd/hotpot/ . You may there choose between a Windows and a Mac version. The graphical guided installation is straightforward and after installation you should register (free for non-commercial use) in order to remove an upper bound on the number of problems in an assignment.

An Overview

Starting up the main program, we get the following graphical interface (here: Windows):

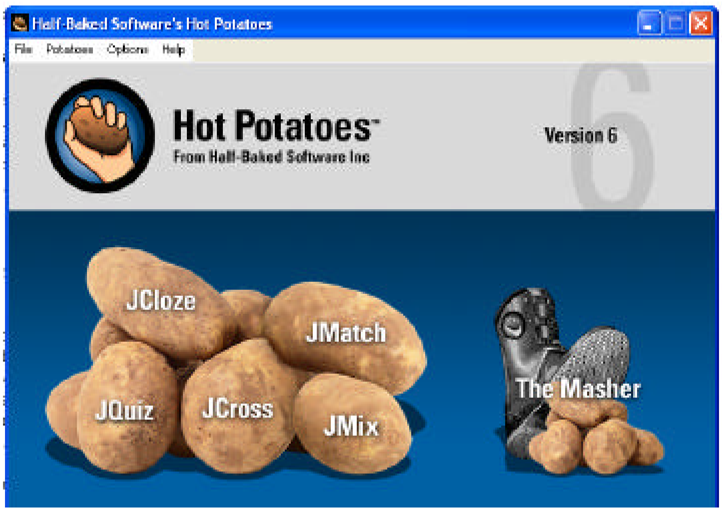


Fig. 1. The main window

Under the help menu in the main program you will find a step-by-step tutorial on the use of each of the five tools ("potatoes") included in the collection. The tools are clickable on this main window and are called JQuiz, JCross, JMix, JMatch, and JCloze for respectively making assignments with question-based quizzes (four types, including multiple-choice), crossword puzzles, jumbled-sentence exercises, matching/ordering exercises, and gap-fill exercises. The last tool on this screen, The Masher, is for organizing web pages. With the Options/Mode menu item you may choose between beginner mode (default) and advanced mode.

For all five potatoes there are three steps involved in designing an assignment:

1. Entering the data
   Questions and answers are written. Pictures, URLs, and certain media objects formats (Windows Media Player, Quick Time Player, RealPlayer, and Flash Player) can also be used.
2. Configuring the output
   If you want the assignment to be done within a certain time limit and/or you want the assignments to be graded and sent to your mailbox, this is the place to make these choices. Most of the other options determine cosmetic issues like colouring, buttoning captions etc.
3. Creating the web pages

Since the procedure is essentially the same for all five tools and there is a very good tutorial from the Help menu, I will only show one simple example of how to design an assignment.

Entering data for a Multiple-Choice Assignment

After clicking the JQuiz potato, I have written a simple wave assignment in the beginner mode:

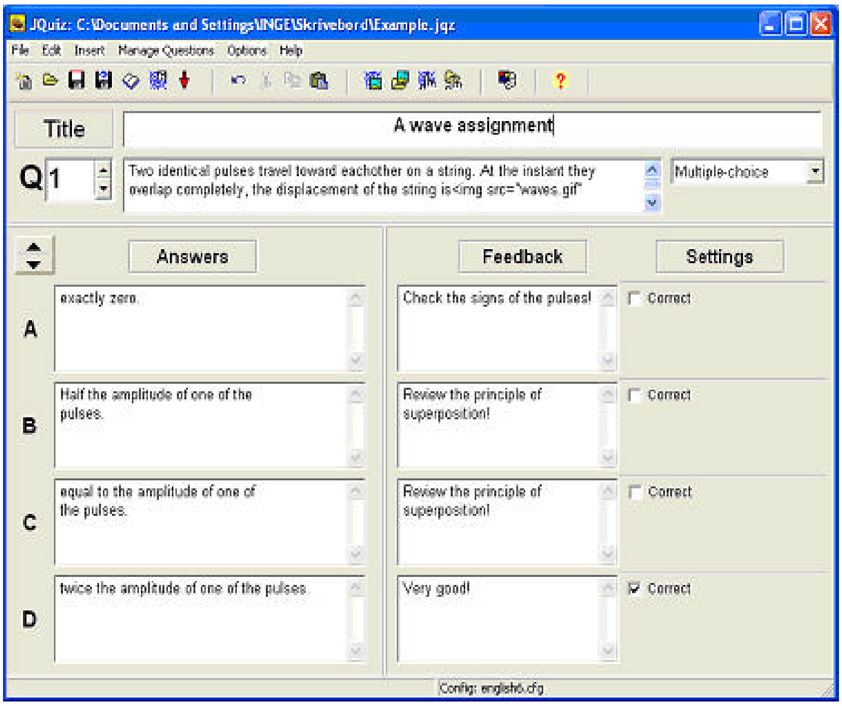


Fig. 2. A simple multiple -choice assignment.

I have filled in the text fields with four potential answers (A – D), filled in the corresponding feedback and ticked off the correct solution. In any text field you may in addition to text insert (via icons or via the Insert menu) pictures, URL links or media objects. In the assignment above, I have inserted a picture in the question text by a standard graphical user interface. The program then generates the HTML code (partly seen in figure 2).

After entering the data for the first question, continue with the next questions by selecting the spin button next to the fat Q letter. When all the questions have been written, we need to configure the output.

Configuring the output

Select the menu Options/Configure Output (or its equivalent icon). Then a collection of tabs appears for configuration. The Titles/Instructions tab is useful for instructions on how the student should respond:

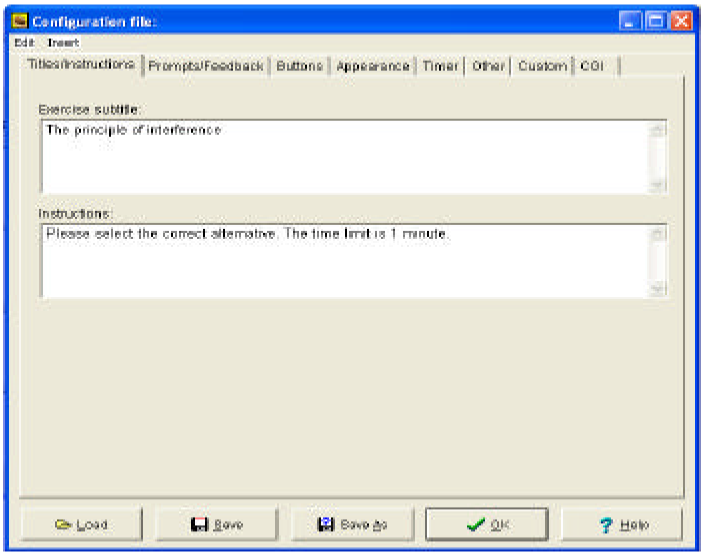


Fig. 3. Configuration window.

With the timer tab you may set a time limit for the assignment, if any (the default is no limit). The CGI tab is important if you want feedback sent to your mailbox. In addition to supplying your email address, the full URL of the standard Perl CGI script FormMail.pl (ask your system administrator) must be given. In the file email.html in the Hot Potatoes 6 folder, you will find a description of what other options you have if you want to use a different script.

Creating the Web Pages

I select the menu File/Create Web page and save the result as an html file. After transferring the file and the question image to my public_html folder (common folder for home pages on Unix/Linux systems) on my web server, the result becomes as shown in figure 4:

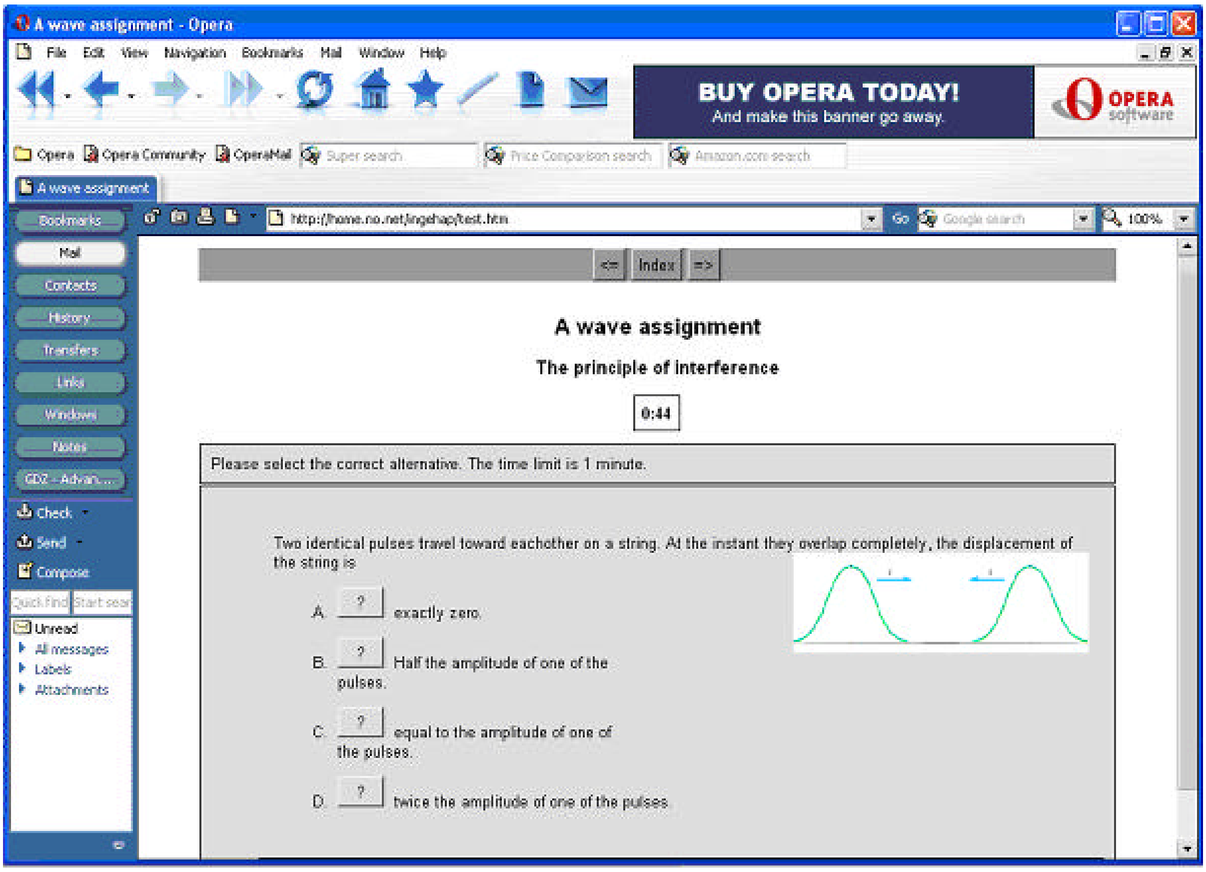


Fig. 4. Final result in the Web browser Opera.

Reviewing the Results

When a student answers the assignment on the Web, she has to give her name in a dialog box. The final result (percentage of total score), the time the test was taken and her name are then sent to you by email.

References

[1] Gregor Novak, Andrew Gavrin, Wolfgang Christian, and Evelyn Patterson, *Just-in-Time Teaching: Blending Active Learning with Web Technology*, Prentice Hall 1999, ISBN 0130850349.

[2] JiTT web page, http://webphysics.iupui.edu/jitt/jitt.html, accessed 10/12 2003.

[3] Eric Mazur, *Peer Instruction: A User's Manual*, Prentice Hall 1996, ISBN 0135654416.

[4] Catherine H. Crouch and Eric Mazur, *Peer Instruction: Ten years of experience and results*, American Journal of Physics, **69** (9), September 2001, pp. 970 – 977.

[5] © Stewart Arneil and Martin Holmes 1997-2003 Half-Baked Software Inc., University of Victoria Humanities Computing and Media Centre.

A List of Physlets

Free online physics simulation software written in Java can be run from a number of web sites. When you design Web assignments (for instance using Hot Potatoes in the previous section), you may give your students a link to such a simulation and ask questions based on this physlet. The aim of this section is to collect resources on the topics mechanics, thermodynamics, electricity and magnetism, optics, and waves. If you want to learn more about the pedagogic ideas behind physlets, a good introduction can be found at Wolfgang Christian's Web site at http://webphysics.davidson.edu/Applets/Applets.html or the references at the end [1-5].

If you want to learn to code your own applets, a Java tutorial for writing applets can be found at the Web site http://java.sun.com/docs/books/tutorial/index.html.

Web sites with physlets in mechanics

http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://www.physics.nwu.edu/vpl
http://jersey.uoregon.edu/vlab/
http://www.developer.com/directories/pages/dir.java.educational.physics.html
http://odin.cbu.edu/~jvarrian/Appcol.htm
http://www3.adnc.com/~topquark/fun/applets.html
http://java.sun.com/contest/winners.html
http://webphysics.ph.msstate.edu/javamirror/
http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://webphysics.davidson.edu/Applets/Applets.html
http://galileoandeinstein.phys.virginia.edu/
http://home.augsburg.baynet.de/walter.fendt/physengl/physengl.htm
http://monet.physik.unibas.ch/~elmer/pendulum/lab.htm
http://www.phy.ntnu.edu.tw/~hwang/
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://icpr.snu.ac.kr/education/applet.html
http://www.phy.syr.edu/courses/javasuite/crosspro.html
http://plabpc.csustan.edu/java/
http://comp.uark.edu/~jgeabana/progr.html

Web sites with physlets in thermodynamics

http://webphysics.davidson.edu/Applets/TaiwanUniv/index.html
http://jersey.uoregon.edu/vlab/
http://galileoandeinstein.phys.virginia.edu/
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://plabpc.csustan.edu/java/
http://comp.uark.edu/~jgeabana/progr.html

Web sites with physlets in electricity and magnetism

http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://webphysics.davidson.edu/Applets/TaiwanUniv/index.html
http://jersey.uoregon.edu/vlab/
http://www.developer.com/directories/pages/dir.java.educational.physics.html
http://odin.cbu.edu/~jvarrian/Appcol.htm
http://shakti.trincoll.edu/~bwalden/phys231.html
http://www3.adnc.com/~topquark/fun/applets.html
http://webphysics.ph.msstate.edu/javamirror/
http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://www.Colorado.EDU/physics/2000/
http://webphysics.davidson.edu/Applets/Applets.html
http://home.augsburg.baynet.de/walter.fendt/physengl/physengl.htm
http://www.phy.ntnu.edu.tw/~hwang/
http://www.public.usit.net/wiarda/index.html
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://www.crs4.it/~mameli/JAVA/LibLabE.html
http://icpr.snu.ac.kr/education/applet.html
http://plabpc.csustan.edu/java/

Web sites with physlets in optics

http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://webphysics.davidson.edu/Applets/TaiwanUniv/index.html
http://www.physics.nwu.edu/vpl
http://jersey.uoregon.edu/vlab/
http://odin.cbu.edu/~jvarrian/Appcol.htm
http://webphysics.ph.msstate.edu/javamirror/
http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://www.Colorado.EDU/physics/2000/
http://galileoandeinstein.phys.virginia.edu/
http://home.augsburg.baynet.de/walter.fendt/physengl/physengl.htm
http://www.phy.ntnu.edu.tw/~hwang/
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://www.crs4.it/~mameli/JAVA/LibLabE.html
http://icpr.snu.ac.kr/education/applet.html
http://plabpc.csustan.edu/java/

Web sites with physlets in waves

http://webphysics.davidson.edu/Applets/TaiwanUniv/index.html
http://odin.cbu.edu/~jvarrian/Appcol.htm
http://webphysics.ph.msstate.edu/javamirror/
http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://www.Colorado.EDU/physics/2000/
http://webphysics.davidson.edu/Applets/Applets.html

http://members.xoom.com/Surendranath/Applets.html
http://home.augsburg.baynet.de/walter.fendt/physengl/physengl.htm
http://www.phy.ntnu.edu.tw/~hwang/
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://plabpc.csustan.edu/java/
http://physics.ham.muohio.edu/fall98/phy171/wave.htm

Web sites with physlets in other topics

http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://webphysics.davidson.edu/Applets/TaiwanUniv/index.html
http://www.physics.nwu.edu/vpl
http://jersey.uoregon.edu/vlab/
http://java.sun.com/contest/winners.html
http://webphysics.ph.msstate.edu/javamirror/
http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
http://www.Colorado.EDU/physics/2000/
http://webphysics.davidson.edu/Applets/Applets.html
http://home.augsburg.baynet.de/walter.fendt/physengl/physengl.htm
http://www.phy.ntnu.edu.tw/~hwang/
http://www.public.usit.net/wiarda/index.html
http://www.gamelan.com/directories/pages/dir.java.educational.physics.html
http://www.crs4.it/~mameli/JAVA/LibLabE.html
http://icpr.snu.ac.kr/education/applet.html
http://plabpc.csustan.edu/java

References

[1] Wolfgang Christian and Mario Belloni, *Physlets: Teaching Physics with Interactive Curricular Material (with CD-ROM)*, Prentice Hall 2000, ISBN 0130293415.

[2] Melissa Dancy, Wolfgang Christian, and Mario Belloni, *Teaching with Physlets®: Examples from Optics*, The Physics Teacher, Vol. 40, Nov. 2002, pp. 494 – 499.

[3] Scott W. Bonham, John S. Risley, and Wolfgang Christian, *Using Physlets to Teach Electrostatics*, The Physics Teacher, Vol. 37, May 1999, pp. 276 – 280.

[4] Anne J Cox, Mario Belloni, Melissa Dancy, and Wolfgang Christian, *Teaching thermodynamics with Physlets® in introductory physics*, Physics Education **38** (Sep. 2003) pp. 433 – 440.

[5] Wolfgang Christian, Web Physics, http://webphysics.davidson.edu/, accessed 10/12 2003.

Labs Sites on the Web

CLEA
Astronomy
http://www.gettysburg.edu/academics/physics/clea/CLEAhome.html

Dick Hake's SDI labs
Mechanics
http://physics.indiana.edu/~sdi

Modeling
Mechanics
http://modeling.asu.edu/

Pasco experiments
www.pasco.com/experiments

Pico Technology
http://www.picotech.com/experiments/index.html

Physics Education Research Groups

General

A good collection of resources based on physics educatiponal research can be found in the article L. C. McDermott and E. F. Redish, *Resource Letter: PER-1: Physics Education Research*, American Journal of Physics, 67 (9), Sep. 1999, pp. 755 - 767. This article can be downloaded from http://www.phys.washington.edu/groups/peg/pubs.html .

Specific groups

Arizona State University
http://modeling.la.asu.edu/modeling.html

Carnegie-Mellon University
http://cil.andrew.cmu.edu/

CNRS-Universite Lumiere-Lyon
http://ignserver.univ-lyon2.fr/SIR/GRIC-COAST/

Dickinson College
http://physics.dickinson.edu/PhysicsPages/Workshop_Physics/Workshop_Physics_Home.htm

Freie Universitat Berlin
http://www.physik.fu-berlin.de/~ag-fischler/

Harvard University, Mazur Group
http://mazur-www.harvard.edu/Education/EducationMenu.html

Harvard University, Science Education Group
http://cfa-www.harvard.edu:80/cfa/sed/

Kansas University
http://bluegiant.phys.ksu.edu/

North Carolina State University
http://www2.ncsu.edu/ncsu/pams/physics/Physics_Ed/

Ohio State University
http://www.physics.ohio-state.edu/~physedu/

Rensselaer Polytechnic Institute
http://www.ciue.rpi.edu/

San Diego State University
http://public.sdsu.edu/CRMSE/

Sydney University
http://www.physics.usyd.edu.au/teach/

Tuft University
http://www.tufts.edu/as/csmt/

Universitat Bremen
http://physik.uni-bremen.de/physics.education/

Universitat Dortmund
http://www.physik.uni-dortmund.de/didaktik/

Universitat Erlangen
http://www.physik.uni-erlangen.de/didaktik/didaktik.html

Universitat Kiel
http://www.ipn.uni-kiel.de/homepage.html

University of California, Berkeley
http://www-gse.berkeley.edu/program/CD/cdprogramsemst.html

University of Main
http://130.111.68.40/PhysicsEducation

University of Maryland
http://www.physics.umd.edu/perg/

University of Massachusetts
http://www-perg.phast.umass.edu/

University of Minnesota
http://www.physics.umn.edu/groups/physed/

University of Nebraska
http://physics.unl.edu/research/rpeg/rpeg.html

University of Utrecht
http://www.fys.ruu.nl/~wwwcdb/Home.html

University of Washington
http://www.phys.washington.edu/groups/peg/

University of the Witwatersrand
http://sunsite.wits.ac.za/wits/fac/science/physics/education.html

Universitat Wurzburg
http://didaktik.physik.uni-wuerzburg.de/

Part VI

Other ICT Resources

Resources on the Use of Spreadsheets in Physics

Since the introduction of VisiCalc in 1979 [1], spreadsheets have served physics students well in their statistical analysis and presentation of experimental data [2-7] and in their modelling of deterministic and nondeterministic physical theories [5-15]. Further, a combination of experimental work with spreadsheets models for the same physical topic will often make the interconnection between experiment and theory more clear [11]. In particular spreadsheets offer a substitute for laboratory work when the needed experimental apparates are expensive and not accessible [8-14]. With strong support for programming and web integration modern spreadsheets continue to be an ideal tool in physics courses.

History

1. For the history of spreadsheets see Walkenbach, *Spreadsheet History*, http://www.j-walk.com/ss/history/index.htm

Data analysis

2. Robert De Levie and Robert Levie, *Advanced Excel for Scientific Data Analysis*, Oxford UP 2003, ISBN 0195152751.

3. Les Kirkup, *Data Analysis with Excel: An Introduction for Physical Scientists*, Cambridge UP 2002, ISBN 0521797373.

4. Richard Feinberg and Max Knittel, "Microcomputer spreadsheet programs in physics laboratory," Am. J. Phys. **53**, 631-634 (July 1985).

Data analysis and Modelling

5. Rick Guglielmino, "Using spreadsheets in an introductory physics lab," Phys. Teach. **27**, 175 (1989).

6. Michael E. Krieger and Jame H. Stith, "Spreadsheets in the physics laboratory," Phys. Teach. **28**, 378 (1990).

7. R. L. Bowman, "Electronic spreadsheets for physics student's use," Am. J. Phys. **56**, 184-185 (Feb. 1988).

Modelling

8. Linda Webb, "Spreadsheets in physics teaching," Phys. Educ. **28**, 77-82 (Mar. 1993).

9. Paula V. Engelhardt, Scott F. Schultz, John E. Gastineau, Margaret H. Gjertsen, and John S. Risley, "Teaching the use of spreadsheets for Physics," Phys. Teach. **31**, 546 (1993)

10. B. A. Cooke, "Some ideas for using spreadsheets in physics," Phys. Educ. **32**, 80-87 (Mar. 1997).

11. See for instance Scott Godsen, “Optimization Analysis of Projectile Motion Using Spreadsheets,” Phys. Teach. **40**, 523 (2002) and Inge H. A. Pettersen, “Experimental Projectile Optimization Analysis,” Phys. Teach. **41**, 132 (2003).

12. S. R. Carson, “Relativity on a spreadsheet,” Phys. Educ. **33**, 80-87 (Mar. 1998).

13. R. Bridges, “Fitting orbits to Jupiter’s moon with a spreadsheet,” Phys. Educ. **30**, 272-276 (Sep. 1995).

14. R. Bridges, “Fitting plantary orbits with a spreadsheet,” Phys. Educ. **30**, 266-271 (Sep. 1995).

15. R. D. Jeffries and K. H. Elliott, “The local population,” Eur. J. Phys. **24**, S17-S24 (Mar. 2003).

16. Annie B. Elliott, Stephen D. Murray, and Richard A. Ward, “Spreadsheet-Based Exercises for Introductory Laboratories,” Phys. Teach. **41**, 18 (2003).

17. T. A. Moore and D. V. Schroeder, “A different approach to introducing statistical mechanics,” Am. J. Phys. **65**, 26-36 (Jan. 1997).

18. J. V. Kinderman, “An computing laboratory for introducing quantum mechanics,” Am. J. Phys. **58**, 568-573 (June 1990).

19. Jesusa Valdez Kinderman, “Investigating the Compton effect with a spreadsheet,” Phys. Teach. **30**, 426 (1992).

20. R. P. Ballingall, “A spreadsheet aid to the study of radioactive decay,” Phys. Educ. **28**, 384-385 (Nov. 1993).

21. S. R. Carson, “Spreadsheets as dynamical modelling tools in investigations at GCSE and beyond,” Phys. Educ. **30**, 89-94 (Mar. 1995).

22. F. Riggi, “Solution of simple numerical problems using spreadsheet programs,” Phys. Educ. **21**, 369-374 (Nov. 1986).

23. R. Kenneth Walter, “Simulating physics problems with computer spreadsheets,“ Phys. Teach. **27**, 173 (1989).

24. Robert J. Beichner, “Visualizing potential surfaces with a spreadsheet,” Phys. Teach. **35**, 95 (1997).

25. Francis X. Hart, “Solving multi-loop circuit problems with a spreadsheet,“ Phys. Teach. **33**, 542 (1995).

26. Peter Drago, “Teaching with spreadsheets: An example from heat transfer,” Phys. Teach. **31**, 316 (1993).

27. Michael T. Frank and Edward Kluk, “Equations of motion on a computer spreadsheet:

The damped harmonic oscillator and more," Phys. Teach. **28**, 308 (1990).

28. John Severn, "Use of spreadsheets for demonstrating the use of simple differential equations," Phys. Educ. **34**, 360-366 (Nov. 1999).

29. Ole Anton Haugland, "Spreadsheet Waves," Phys. Teach. **37**, 14 (Jan. 1999).

30. Gordon J. Aubrecht II, T. Kenneth Bolland, and Michael G. Ziegler, "Animations in Spreadsheets," Phys. Teach. **37**, 540-541 (Dec. 1999).

31. Charles Misner, *Spreadsheet Physics*, Addison-Wesley 1998, ISBN 0201834375.

32. Raymond A. Servay, *Spreadsheet for Principles of Physics*, Harcourt Brace and Company 1997, ISBN 0030206596.

33. Frank Potter, Charles W. Peck, David S. Barkley, *Dynamic Models in Physics: A Workbook of Computer Simulations Using Electronic Spreadsheets: Mechanics*, N. Simonson 1989, ISBN 0962255610.

Resources on Data Logging

Books

C. Brueningsen and W. Krawiec, *Exploring Physics and Math with the CBL System: 48 Lab Activities Using CBL and the TI-82*, Texas Instruments
Sample activities can be found at http://www.ti.com/calc/docs/cbl2_27.htm and http://www.ti.com/calc/docs/cbl2_31.htm.

P. Laws, *Workshop Physics Activity Guide*, Wiley, New York 1997

D. R. Sokoloff, R. K. Thornton, and P. W. Laws, *RealTime Physics. Active Learning Laboratories. Module 1: Mechanics*, Wiley, New York 1999, ISBN 0-471-28379-7

D. R. Sokoloff, R. K. Thornton, and P. W. Laws, *RealTime Physics. Active Learning Laboratories. Module 2: Heat and Thermodynamics*, Wiley, New York 1999, ISBN 0-471-28378-9

R. D. Knight, Five Easy Lessons: strategies for Successful Physics Teaching

ed. Barbara J. Duch, *The Power of Problem-Based Learning: A Practical "How To" for Teaching Undergraduate Courses in Any Discipline*

Lillian C. McDermott and Peter D. Shaffer, *Tutorials In Introductory Physics and Homework Package*

Lillian McDermott et al, *Physics by Inquiry*

Thomas L. O'Kuma et al, *Ranking Task Exercises in Physics*

A. B. Arons, *Teaching Introductory Physics*, Wiley, New York 1997

Articles

Distribution Lists

General

Among other companies in the electronic mailing list software business are LISTPROC, Majordomo, Mailstorm, ListStar, LetterRip, and AutoShare. In general, distribution lists contain a lot of information related to physics: Searching the catalog of listserv lists Catalist, http://www.lsoft.com/lists/list_q.html, for "physics" gave in September 2003 totally 119 lists related to physics.

The article D.L. MacIsaac, "Communities of on-line physics educators", The Physics Teacher 38(4), 210-213 (2000) contains more information about distribution lists and can be found online at the Phys-L homepage http://purcell.phy.nau.edu/phys-l/.

Physics

Post to PHYS-L	http://lists.nau.edu/cgi-bin/wa?P1&L=phys-l
Join/leave PHYS-L	http://lists.nau.edu/cgi-bin/wa?SUBED1=phys-l&A=1
Browse PHYS-L	http://lists.nau.edu/archives/phys-l.html
Search PHYS-L	http://lists.nau.edu/cgi-bin/wa?S1=phys-l

Physhare <http://lists.psu.edu/archives/physhare.html>,
Phys-L <http://mailgate.nau.edu/archives/phys-l.html>,

Chemistry

Chemed-L <http://www.optc.com/chemed-l-thread>.
<http://jchemed.chem.wisc.edu/ChemEd/ChemEdL/>

Biology

http://listserv.ksu.edu/archives/biopi-l.html
http://biology.clemson.edu:591/biolab/search.htm